CHAPTER 4

Environmental and Economic Consequences

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Chapter 4 Environmental and Economic Consequences

This Programmatic Supplemental Environmental Impact Statement (SEIS) has so far presented the preliminary information necessary to analyze the potential impacts that may follow from implementation of any of the four policy alternatives. We have explained the purpose and need for federal action (Chapter 1); we have reviewed the legal context of federal fisheries management in Alaska and the tools managers use to satisfy those legal requirements (Chapter 2); also in Chapter 2, we defined the alternatives presented in this document and the fishery management plan (FMP) bookends created to illustrate the range of management measures that might be taken to implement a given policy alternative; and in Chapter 3, we defined the environmental and economic baseline conditions against which to measure the impacts of the alternatives.

We now turn to the work of analyzing the possible impacts of the alternatives. Chapter 4 presents our analysis of the FMP bookends and the environmental and economic impacts that might reasonably be expected to follow from implementation of the suite of management measures contained in each FMP bookend. The analyses contained in this chapter will thus allow readers to evaluate the relative effectiveness of the policy alternatives in meeting the legal, environmental, and economic demands of the federal groundfish fisheries off Alaska.

Analysis of the impacts of management policies requires knowledge of potential actions that could be taken to implement the policy. Policies are, by definition, a high-level, overall statement or plan embracing the general goals and procedures of a government body. In the United States (U.S.), they usually reflect the values and wisdom of its citizens, as expressed by laws and agencies of the nation. Policy goals and objectives are often used to frame the policy and make the statement clearer and easier to understand. Still, determination of the effects of a policy on the human environment is difficult to comprehend and analyze without some indication of how the policy might be implemented.

This chapter, then, evaluates a number of example FMPs intended to illustrate a particular policy as defined by the alternatives described in Section 2.4.1. In doing so, we will be able to better understand the current management policy governing federal management of the groundfish fisheries off Alaska, as well as the likely tradeoffs should the existing policy be changed to reflect a new management approach. Since we had no proposed alternative management policies or alternative FMPs to consider at the outset of the Programmatic SEIS process, National Marine Fisheries Service (NOAA Fisheries or NMFS) has relied heavily on comments received during public scoping process and on the 2001 Draft Alaska Groundfish Fisheries Programmatic SEIS in crafting the alternatives. NOAA Fisheries consulted frequently with the North Pacific Fisheries Management Council (NPFMC) in developing the alternatives by relying on their expertise and judgement, and on the public scoping process.

Significant changes to the structure and organization of this chapter have been made in response to public comments on the 2001 Draft Programmatic SEIS. As we explained in Chapter 2, we have restructured the policy alternatives to better reflect a multi-species, ecosystem management approach. Each of the policy alternatives (Alternatives 1 through 4) now represents a different management approach, ranging from a more aggressive harvest strategy (Alternative 2) to a very restricted harvest strategy where fishing is only authorized upon proof that no adverse impacts will occur (Alternative 4). Two intermediate policy alternatives are presented: Alternative 1, continue the current risk averse policy, and Alternative 3, adopt a more precautionary policy). Each policy alternative contains a suite of policy goals and objectives, each addressing to various degrees the important components of the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) marine ecosystem.

To help both the decision-maker and the public understand what a policy means and what environmental consequences may occur, we have defined example FMPs to illustrate each policy. These example FMPs contain a number of FMP components that were identified by the public as important features of any fishery management program. The best example of the current management policy are the current BSAI and GOA Groundfish FMPs. For Alternatives 2 through 4, we define two example FMPs, each comprised of a different combination of management tools and tool applications. Each of these example FMPs contain concepts or specific suggestions obtained from NPFMC and the public. From an overall programmatic perspective, the actual characterization of the example FMPs and their effects is not as important as what is learned about the environmental trade-offs one can expect when considering alternative management policies governing the Alaska groundfish fisheries. Understanding these general environmental trade-offs will enable NPFMC, NOAA Fisheries, and the public to collectively shape future management policy and identify potential alterations to the existing management program.

The example FMPs also satisfy another purpose. NOAA Fisheries has determined that providing a management framework can help guide and communicate the direction of future actions. This is accomplished by including as an element of the preferred alternative, two example FMPs that serve as "bookends" to a range of management actions, recognizing their inherent environmental consequences. Each example FMP will be analyzed separately and will proxy a range of future management actions. The bookend framework, comprised of two example FMPs, will indicate the range of environmental effects of that policy. The FMP bookends are not intended to be stand alone alternatives. The FMP bookends are examples of management plans that are driven wholly by the policy statements. They illustrate different ways the groundfish fisheries can be managed and the range of environmental effects that can be expected from the implementation of a policy alternative. A FMP framework will be included in NPFMC's and NMFS' final decision, and will be used to define a range of management actions that will be pursued following completion of the Programmatic SEIS. This alternative structure recognizes that the resource being managed as well as the marine ecosystem is quite dynamic in nature and only partially understood. Providing a range of management tools and their potential effects for each policy alternative is an attempt to take into account the dynamic nature of the fisheries as a whole and to provide enough management program flexibility in each alternative to allow decisions based on the best available science.

Analyzing such a complex set of alternatives is difficult. Presenting our analysis in a single chapter of the Programmatic SEIS also has its challenges. This is first provided in Section 4.1, a description of the methods used to evaluate the alternatives and their associated FMP bookends. This section defines the term significance, describes how data gaps and incomplete information are delt with, defines what is meant by direct, indirect, and cumulative effects, and provides a technical description of the multi-species model and its assumptions. Section 4.2 describes the concept of the FMP bookends and provides a detailed summary of each of the example FMP components used as proxies for a policy alternative. Section 4.3 provides the public with a qualitative examination of each FMP component and discusses the range of management measures that could later serve as plan amendments. In this qualitative assessment section, the public is provided with a general review of the likely environmental effects that could be expected from each of the measures, across example FMPs (Figure 4.0-1; illustrating the "row look"). This section is intended to provide the public with information on what could be expected from each management tool (in relative isolation from other plan components), across a range of environmental effects categories as well as an indication on how well these management tools may meet a particular set of policy objectives.

The Programmatic SEIS continues by reviewing in Section 4.4, the statements defining the current environmental baseline from which all the alternatives and their associated example FMPs will be compared. These baseline statements developed in Chapter 3, provide an important reference point for this Programmatic SEIS. Sections 4.5 through 4.8 analyze Alternatives 1 through 4 by examining their associated example FMPs as proxies. Each FMP is analyzed as a whole (Figure 4.0-2; illustrating the "column look") so as to represent the entire FMP and all of its components. This is a marked departure from the 2001 Draft Programmatic SEIS document and is the result of considerable public input. Another difference between this and the 2001 Draft Programmatic SEIS is that this chapter is organized around alternatives, rather than by resource categories. Many members of the public recommended this organization as an improvement over the earlier draft.

Section 4.9 presents a policy analysis of each of the alternatives using the potential impacts of the example FMPs as a guide. Evaluation of each alternative in terms of satisfying the Magnuson-Stevens Fishery Conservation and Management Act (MSA), Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and other applicable federal law is provided. Section 4.10 concludes this chapter by providing the public with an overall comparison of the alternatives at the policy level.

At this point, we feel obliged to beg the reader's continuing patience. The following analyses are unavoidably lengthy. We have tried to err on the side of inclusiveness, rather than run the risk of omitting any information or analysis that might aid decisionmakers and the public in evaluating the relative merits of the alternatives. Also, the description of modeling methods in Section 4.1.5 contains highly technical information and mathematical equations that we have seen fit to place here in introducing the analysis, rather than consign to an appendix. Although we do not expect that all readers will want to follow these equations variable by variable, we have placed the description of methods prominently for public scrutiny of the scientific rigor with which the analyses have been conducted. Yet, however lengthy, detailed, and technical the analyses, we have tried our best where possible to keep the information accessible to the reader.

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4.1 Methodology

Alternatives are analyzed in the Programmatic SEIS to determine their environmental impacts. As previously described at the beginning of this chapter, each alternative is analyzed first at the FMP-level, and later at the policy-level. The FMP-level analysis examined both individual components as well as all of the components together, using the example FMPs, to determine the significance and intensity of impacts. A number of analytical models were used to conduct this analysis.

Section 4.1.1 discusses the significance thresholds used to analyze the impacts of the alternative, and Section 4.1.2 explains how data gaps and incomplete information were dealt with in this document. Section 4.1.3 describes the methodology for the direct and indirect effect analysis, and Section 4.1.4 for the cumulative impact assessment. Section 4.1.5 describes the multi-species model, Section 4.1.6 describes the habitat model, and Section 4.1.7 describes the sector model used to estimate socioeconomic effects.

4.1.1 Determining Significance of Potential Consequences

The National Environmental Policy Act (NEPA) requires that an Environmental Impact Statement (EIS) include:

> ... the environmental impacts of the alternatives including the proposed action, any adverse environmental effects which cannot be avoided should the proposal be implemented, the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and any irreversible or irretrievable commitments of resources which would be involved in the proposal should it be implemented (40 Code of Federal Regulations [CFR] 1502.16).

The EIS analysis must also identify whether an adverse environmental effect is significant. Significance is determined by considering the contexts (geographic, temporal, societal) in which the action will occur, and the intensity of the action. The evaluation of intensity should include consideration of the magnitude of the impact, the degree of certainty in the evaluation, the cumulative impact when the action is related to other actions, the degree of controversy, and violations with other laws.

In this Programmatic SEIS, significance thresholds have been determined for each resource category (target species, socioeconomic effects, ecosystem, etc.). In some instances, although the significance threshold remains the same, the qualifier 'conditional' is assigned. This indicates that a significant impact is assumed, based on credible scientific information and professional judgement, but that more complete information is needed for certainty. The following impact ratings may be used for each resource category:

Significantly Adverse (S-): Significant adverse effect in relation to the reference point and based on ample information and data and the professional judgement of the analysts who addressed the topic.

Conditionally Significant Adverse (CS-): Conditionally significant adverse effect in relation to the reference point; this determination is lacking in quantitative data an information; however, the professional judgement of the analysts is that the alternative will cause a decline in the reference point condition.

Insignificant Impact (I): Insignificant effect in relation to the reference point; this determination is based on information and data, along with the professional judgement of the analysts, that suggest that the effects will not cause a significant change to the reference point condition.

Conditionally Significant Beneficial (CS+): Conditionally significant beneficial effect in relation to the reference point; this determination is lacking in quantitative data and information; however, the professional judgement of the analysts is that the alternative will cause an improvement in the reference point condition.

Significantly Beneficial (S+): Significant beneficial effect in relation to the reference point and based on ample information and data and the professional judgement of the analysts who addressed the topic.

Unknown (U): Unknown effect in relation to the reference point; this determination is characterized by the absence of information and data sufficient to adequately assess the significance of the impacts, either because the impact is impossible to predict, or because insufficient information is available to determine a reference point for the resource, species, or issue.

These ratings are applied to resource-specific impact indicators in the following resource categories: target species, prohibited species, other species, forage fish species, non-specified species, habitat, seabirds, marine mammals, socioeconomic effects, and ecosystem effects. The specific application for each is described below.

4.1.1.1 Target Species, Prohibited Species, Other Species, Forage Fish Species, Non-Specified Species

The significance of the impacts on target species, prohibited species, forage fish species, other species, and non-specified species was evaluated with respect to five effects: 1) fishing mortality, 2) change in biomass level, 3) spatial/temporal concentration of the catch, 4) prey availability, and 5) habitat suitability. The significance of these effects was evaluated as to whether the impacts, within the current fishery management regime, may be reasonably expected to jeopardize the sustainability of each target species or species group.

Target species are unique in that thresholds for overfishing and stock size have been developed (Amendment 56/56 to the BSAI and GOA FMPs) that relate to sustainability of the stock. As such, these thresholds are used to evaluate the significance of the effects of the example FMPs relative to their impacts on the sustainability of the target species. Fishing mortality rates that exceed the overfishing mortality rate are considered to jeopardize the capacity of the stock to produce maximum sustainable yield (MSY) on a continuing basis and adversely impact the sustainability of the stock. A related measure of this potential is indicated by change in biomass levels. The significance of effects of the current spatial/temporal concentration of the catch, and the level of prey availability and habitat suitability for target species is evaluated with respect to each stock's current size relative to its maximum stock size threshold (MSST). An action that jeopardizes the stock's ability to sustain itself at or above its MSST is considered to adversely affect the sustainability of the stock.

The significance of the five selected effects is evaluated according to the specific criteria for the impact ratings (Tables 4.1-1, 4.1-2, and 4.1-3). Species or species complexes that fall within Tiers 1 though 5 have estimates of the current fishing mortality rates and are evaluated with respect to exceeding the overfishing mortality rate (fishing mortality effect). Species or species complexes that fall within Tiers 1, 2, or 3 have reliable estimates of MSST and are evaluated for the effects of spatial/temporal concentration of the catch, prey availability, and habitat suitability. Species or species complexes that fall within Tiers 4, 5, or 6 do not have reliable estimates of MSST and therefore cannot evaluate for the significance of these effects. This inability to evaluate the significance of the effects also occurs for the forage, prohibited and non-specified species. Since several species or species complexes do not have estimates of abundances-at-age, in this version of the model their abundance levels simply reflect the most recent estimate. For these groups, analysis of the effects of the example FMPs was limited to catch projections and likely consequences given patterns in related fauna.

4.1.1.2 Habitat

The potential effects of the groundfish fisheries on habitat used to compare the alternatives were the mortality of and damage to living habitat, changes to benthic community diversity, and changes to the geographic diversity of impacts and protection. Specific impacts are very difficult to predict. Evaluation of effects requires detailed information on the distribution and abundance of habitat types, the life history of living habitat, habitat recovery rates, and the natural disturbance regime. This information is generally incomplete.

Qualitative judgments as to the significance of effects were made after considering information on 1) bycatch of living habitat derived from the multi-species projection model; 2) the results of a habitat impacts model for estimates of the equilibrium levels of living habitat in fishable and currently fished areas; 3) estimates of the amount of area by habitat type and geographic zone closed year round to bottom trawling for all species; and 4) evaluation of the spatial distribution of bottom trawl closures relative to fishing intensity and habitat types. The evaluation criteria are described in Table 4.1-4. Significance determination in this analysis differs from the more commonly used approach in scientific research. Typically, the null hypothesis of no effect is tested rigorously and only rejected if there is a very low probability of it being true (Type I error). Scientists are trained to minimize the chance of a Type I error. In this Programmatic SEIS analysis however, rigorous tests of available data to reject the hypothesis of no fishing effects were not relied upon to determine significance. This was done for two reasons. First, there was very little data available to detect fishing effects, so rigorous statistical testing for a Type I error could not be performed. Second, it was believed that a more appropriate approach for this Programmatic SEIS was to decrease making a Type II error (accepting a hypothesis of no effect to habitat when it is in fact false). Reducing the probability of making a Type II error is more precautionary and is more responsive to both essential fish habitat (EFH) mandates and the public comment received on the 2001 draft Programmatic SEIS.

During the course of preparing the revised draft Alaska Groundfish Fisheries Programmatic SEIS, comments and questions were raised about the purpose and scope of the Programmatic SEIS and the agency's EFH EIS that is currently being prepared on a separate schedule. In response to these questions and to clarify their purpose and need, the following summary compares the two analyses.

The Alaska Groundfish Programmatic SEIS and its Relationship to the Ongoing Essential Fish Habitat EIS

The Essential Fish Habitat EIS and Groundfish Programmatic SEIS have different scopes and areas of focus.

EFH EIS. The analyses herein consider adverse effects of fishing on benthic marine habitat from the perspective of managed fish species that are dependent on certain qualities and features of that habitat. As such, the scope of this work is more narrow than a consideration of these changes at the scale of entire marine ecosystems (as pursued in the Programmatic SEIS, for example).

Programmatic SEIS. The analyses herein consider adverse effects of fishing on benthic marine habitat from the perspective of ecosystem structure and function, as well as managed fish species. As such, the scope of this work is broader than a consideration of these changes on commercially-important and functionally dependent fish species.

These differences are reflected in the issues, criteria, and assessments made in each EIS. To a lesser extent, the information available for analysis in each EIS was different because the Programmatic SEIS was developed on an earlier schedule than the EFH EIS.

The purpose and need of the two documents is different as are their respective scope and alternatives. Table 1 summarizes the principal differences between these EISs.

Table 1. Major differences between the Alaska Groundfish Fisheries Programmatic SEIS and the EFH EIS.

	Programmatic SEIS	**EFH EIS**
Purpose and Need	Programmatic review of BSAI and GOA groundfish FMPs and their effects on the marine ecosystem	Review of alternatives for identifying EFH, identifying HAPCs, and minimizing adverse effects of fishing on EFH for groundfish, crabs, salmon, and scallops
Action	Broad scope: Reauthorization of all groundfish fisheries under MSA, ESA, MMPA, and other applicable law; set policy	Narrower scope: Consider revising EFH designations and adopting mitigation measures to reduce the effects of fishing on EFH
Alternatives	Broad multi-objective policies	Alternative EFH designations, approaches to identifying HAPCs, and mitigation measures
Source of closed areas used in analysis	Based on public comments on 2001 draft Programmatic SEIS, EFH Cmte (Fall 2002) concepts, internal analysis	EFH Committee (finalized by NPFMC in April 2003)
Legal Authority	Under MSA, agency can take action to protect habitat even if not specified as EFH	Under MSA, agency <u>must</u> minimize to the extent practicable adverse effects of fishing on EFH

Notes: BSAI - Bering Sea/Aleutian Islands
EFH - essential fish habitat
EIS - Environmental Impact Statement
GOA - Gulf of Alaska
HAPC - habitat area of particular concern
MMPA - Marine Mammal Protection Act
MSA - Magnuson-Stevens Act

The differences between the analyses used to assess the effects of fishing on habitat are outlined in Table 2. While the Programmatic SEIS looked only at bottom trawl impact, bottom trawl fisheries were the predominant source of habitat impacts in the EFH EIS which also examined trawl, dredge, pot, and longline gear. Another difference was that the Programmatic SEIS usually cited results using the upper recovery value for soft bottom habitats (15 years, higher effects), while the EFH analysis used a central value (5.5 years). However, both EISs acknowledge that impacts to benthic habitat occur in areas of high fishing intensity regardless of the recovery rate assumed in the analysis. The same quantitative model relating fishing effort to habitat impact was used in both EISs and the results were highly comparable with only subtle differences, which had little effect on the ratings or discussion in the two EISs.

Table 2. Differences in Data and Methods for Habitat Effect Analysis and Evaluation Issues.

	Programmatic SEIS	**EFH EIS**
Input data source	Bottom Trawl Only	Trawl, dredge, pot, longline
Years	1997-2001	1998 - 2002
Fishery Class	Trawl	By target species and gear
Living Substrate Recovery Time (Soft bottom)	2 and 15 years 200 years for coral	3.8, 5.5, and 10 years
Habitat Issues	Living habitat mort./damage including coral Benthic Community and Geographic Impact diversity	Prey availability Epibenthic structure Coral
Managed Fish Habitat Issues	Habitat Suitability	Spawning/breeding Feeding Growth to maturity

Notes: EFH - essential fish habitat
EIS - Environmental Impact Statement

The Programmatic SEIS baseline evaluation and the EFH effects of fishing evaluation had different purposes which reflected their emphases on ecosystem/community concerns and welfare of managed species, respectively. The Programmatic SEIS baseline evaluation identified areas of high impact on living substrates and noted the estimated high potential impact level to benthic living structure and the size of affected areas. The analysis also considered the likelihood that those areas represent a unique habitat for managed fish species as determined by geography and oceanography, and not equivalent to all other habitat in the same classification. the analysis also concluded that coupled with historical impacts, impacts to long-lived, slow growing species (i.e., coral) could cause long term damage and possibly irreversible loss of living habitat, especially in the Aleutian Islands. The baseline impact to benthic habitat was therefore rated as conditionally significant adverse. For purposes of making policy decisions, it is important that any potential significant adverse effects, even if conditional, be presented to decision makers and the public so that consideration can be given to these effects when developing management measures in the future.

The EFH effects of fishing evaluation describes the same areas of high effect to habitat features identified in the Programmatic SEIS, but goes on to evaluate the expected effects of all such reductions on the welfare of each managed species. Those evaluations include areas occupied by each species, available information on their use of the habitat, and the stock history of each species. The Programmatic SEIS analysis evaluated impacts to the habitat itself, focusing on habitat features that might provide functions to managed species and speculated that linkages to productivity existed. Considering the paucity of information on habitat function for species life history stages and the broader scope of the Programmatic SEIS, it did not depend on finding proof of such linkages. The EFH analysis examined the likelihood of significant linkages between habitat effects and the welfare of each managed species to determine whether the effects of fishing on EFH of managed species are more than minimal and not temporary. The purposes and methods of analysis are discussed in more detail in Appendix B of the EFH EIS.

The approach and methodology employed to assess the impacts on target groundfish species in the Programmatic SEIS and EFH EIS were similar. For each species in each EIS, a knowledgeable scientist was designated to perform an evaluation of whether the alternatives affected the welfare of each species in question relative to a number of key issues. In the Programmatic SEIS, the key issues were: 1) fishing mortality, 2) change in biomass level, 3) spatial/temporal concentration of the catch, 4) prey availability, and 5) habitat suitability. The key issues analyzed in the EFH EIS were: 1) stock biomass, 2) spatial/temporal concentration of the catch, 3) spawning/breeding, 4) feeding, and 5) growth to maturity. These issues were evaluated relative to the status quo fishery, as well as to the alternatives developed under each EIS. Criteria were established for each issue to assist the analysts in making their evaluations. The primary consideration in these evaluations revolved around the ability of the stock to maintain its health and support a sustainable fishery.

In the National Standard Guidelines to the MSA, sustainability is defined relative to a MSST, where stocks below the MSST are considered sufficiently small as to require an appropriate rate of rebuilding. This concept of sustainability was used in the Programmatic SEIS and EFH EIS to maintain consistency with the National Standard Guidelines. For Tier 3 fish stocks, estimated recruitments from the late 1970s to the present were used in defining MSST proxies. These estimated recruitments thus cover a range of recent history when impacts to the stock from fishing practices would be expected. Additionally, 10 year projections were made to assess whether the stock would be likely to fall below their MSST level under the status quo harvesting policy. In the EFH EIS, these projections were not available for the remaining mitigation alternatives. However, because each of the mitigation alternatives represents a more conservative harvest policy than the status quo alternative, a finding of stock status above the MSST under the status quo alternative could reasonably be expected to hold under the remaining alternatives.

It should be noted that the MSST criterion was not the only metric used for the evaluation. For some stocks, information is known about habitat associations and how these may be impacted under various harvesting regimes, from both previous studies and the results from the Fujioka-Rose model. This material is presented in the text of the EFH EIS as part of the more focused look at the linkages between habitat impacts and sustainability. Additionally, for stocks in Tiers 4-6, MSST is not available, and an evaluation is based on professional judgment using the best available scientific information and evidence.

Analyses of the Effects of Fishing on Habitat

The Programmatic SEIS baseline evaluation and the EFH effects of fishing evaluation had different purposes which reflected their emphases on ecosystem/community concerns and welfare of managed species, respectively. The Programmatic SEIS baseline evaluation identified 8,000 square miles of the Bering Sea with high impact values for living substrates. The analysis also considered the high fishing effort as an indication that those areas represent a unique habitat for managed fish species as determined by geography and oceanography, and not equivalent to all other habitat in the same classification. The analysis also concluded that coupled with historical impacts, impacts to long-lived, slow growing species (i.e., coral) could cause long term damage and possibly irreversible loss of living habitat, especially in the Aleutian Islands. The baseline impact to benthic habitat was therefore rated as conditionally significant adverse. The Programmatic SEIS analysis evaluated impacts to the habitat itself, focusing on habitat features that might provide functions to managed species and speculated that linkages to productivity existed. Considering the lack of information on habitat function for species life history stages and the broader scope of the Programmatic SEIS, the Programmatic SEIS analysis did not depend on specifically demonstrating such linkages. For purposes of making policy decisions, it is important that any potential significant adverse effects, even if conditional, be presented to decision makers and the public so that consideration can be given to these effects when developing management measures in the future.

The EFH Effects of fishing evaluation described the same areas of high effect identified in the Programmatic SEIS, as well as broader areas of lesser effects to habitat features. Aggregate reduction values were computed by habitat areas and species EFH areas. The evaluation then goes on to consider the expected effects of all such reductions on the welfare of each managed species. Species-level evaluations included areas occupied by each species, available information on their use of the habitat and the stock history of each species. The EFH analysis examined the likelihood of significant linkages between habitat effects and the welfare of each managed species.

While the Programmatic SEIS baseline evaluation identified areas of concern regarding of the current state of habitat effects from fishing, the EFH EIS was designed to specifically address criteria set in the EFH final rule. While identifying areas of concern was one step in the EFH EIS, the ultimate purpose of this analysis is to evaluate whether the effects of fishing had negative effects on the Essential Fish Habitat of managed species that was more than minimal and not temporary. Specific meaning of these terms are discussed in Appendix B of the EFH EIS.

<u>Comparisons of the Alternatives</u>

The approach and methodology employed to assess the impacts on target groundfish species associated with each alternative in the Programmatic SEIS and EFH EIS were similar. For each species in each EIS, a knowledgeable scientist was designated to perform an evaluation of whether the alternatives affected the welfare of each species in question relative to a number of key issues. In the Programmatic SEIS, the key issues were: 1) fishing mortality, 2) change in biomass level, 3) spatial/temporal concentration of the catch, 4) prey availability, and 5) habitat suitability. The key issues analyzed in the EFH EIS were: 1) stock biomass, 2) spatial/temporal concentration of the catch, 3) spawning/breeding, 4) feeding, and 5) growth to maturity. These issues were evaluated relative to the status quo fishery, as well as to the alternatives developed under each EIS. Criteria were established for each issue to assist the analysts in making their evaluations. The primary consideration in these evaluations revolved around the ability of the stock to maintain its health and support a sustainable fishery.

In the National Standard Guidelines to the MSA, sustainability is defined relative to a MSST, where stocks below the MSST are considered sufficiently small as to require an appropriate rate of rebuilding. This concept of sustainability was used in the Programmatic SEIS and EFH EIS to maintain consistency with the National Standard Guidelines. For fish stocks where information is available to estimate recruitment (Tiers 1, 2, or 3), recruitments from the late 1970s to the present were used in defining MSST proxies. These estimated recruitments thus cover a range of recent history when impacts to the stock from fishing practices would be expected. As part of the Programmatic SEIS, 10 year projections were made to assess whether the stocks would be likely to fall below their MSST level under the status quo harvesting policy and each of the alternative policies. In the EFH EIS, projections were not available for the non-status quo mitigation alternatives. However, because each of the EFH EIS mitigation alternatives represents a more conservative management policy than the Programmatic SEIS status quo alternative, it can be reasonably expected that the stock status of managed species would continue to remain above the MSST under all EFH mitigation alternatives.

It should be noted that the MSST criterion was not the only metric used for the evaluation. For some stocks, information is known about habitat associations and how these may be impacted under various harvesting regimes, from both previous studies and the results from the Rose application of the habitat impact model. This material is presented in the text of the EFH EIS due to the more focused look on the linkages between habitat impacts and sustainability. Additionally, for stocks in Tiers 4-6, MSST is not available, and an evaluation is based instead on professional judgement using the best available scientific information and evidence.

4.1.1.3 Seabirds

Significance criteria were based on whether the proposed action would be likely to result in population level effects, defined as changes in the population trend outside the range of natural fluctuations. The projection model was used for predictions of fishing effort under the different FMP bookends, especially with respect to different gear types. The analysis also includes other factors such as spatial/temporal restrictions and potential gear modifications for seabird avoidance. However, because there are a large number of unpredictable variables and gaps in our knowledge about particular species and ecosystem effects, it was impossible to ascertain significance on a strictly quantitative basis. Conclusions are based on professional judgement of pertinent data and literature review.

Except for the supplemental food provided by the fisheries in the form of offal, the effects of the fisheries are all considered adverse to individual birds. Low levels of incidental take are better for conservation purposes than high levels of take, but no amount of incidental take can be considered beneficial to a seabird population. The significance ratings for incidental take are therefore only insignificant or adverse. Although the number of seabirds that would be expected to be taken under the alternative FMPs varies considerably, this difference is not discernible by looking at a shared “insignificant” rating. The same type of situation applies to fishery-induced changes in benthic habitat so there is no beneficial rating for this effect. Effects of the fishery on food availability could be adverse, insignificant, or beneficial. If there is a plausible mechanism and a reasonable set of conditions under which an effect may occur under a given FMP, the significance rating may be labeled “conditional.” If there is a plausible mechanism for an effect but not enough data to assess whether it occurs or whether the FMP would create the conditions under which it would occur, the significance rating may be “unknown.” The evaluation criteria are described in Table 4.1-5.

Species were grouped according to the similarity of their response to the groundfish fishery and/or similarity in their management status. Two species were analyzed on their own and the rest were discussed in five groups. The species categories and the main reason for their distinctions are listed below:

1. Short-tailed albatross (listed as “endangered” under the ESA, have played a central role in the development of seabird protection measures).

2. Laysan and black-footed albatross and shearwaters (do not breed in Alaska, feed on or near the surface of the water).

3. Northern fulmars (the most frequently taken species in every groundfish gear type).

4. Species of Management Concern (a U.S. Fish and Wildlife Service [USFWS] designation for species that may be susceptible to listing under the ESA, including red-legged kittiwakes, marbled murrelets, and Kittlitz’s murrelets).

5. Other piscivorous (fish-eating) species (most alcids, gulls, and cormorants).

6. Other planktivorous species (storm-petrels and auklets).

7. Spectacled and Steller’s eiders (benthic feeding sea ducks listed as “threatened” under the ESA).

4.1.1.4 Marine Mammals

The standard for determining significance for effects on marine mammals was whether the impact would be expected to be detectable at the population level. Individual effects categories do not have to cause a measurable population decline or increase to be labeled significant, but data and/or plausible arguments must exist to determine that the action would have more than a negligible impact on the reproduction and/or survival of a species group such that the population could be affected.

For each category of effects, it was determined if the alternative fishing regime would result in significant adverse, insignificant, significant beneficial, or unknown effects on marine mammals. In addition, effects may be classified as conditionally significant if significant effects could be expected under a plausible set of conditions. The intent of the conditional label is to imply uncertainty about whether an alternative FMP would actually result in conditions that led to a significant impact. When the conditional label is applied, a plausible mechanism for the impact and the conditions under which a significant impact would be realized is stated. In cases where data are lacking to rank an effect according to the significance criteria, the effect was determined to be “unknown.”

The expected effects of each alternative were compared to the effects as they exist under the baseline conditions to determine the relative significance of the impacts on marine mammals. The evaluation criteria are described in Table 4.1-6.

4.1.1.5 Socioeconomic Effects

In the socioeconomic impact analysis, the term "significant" for an expected change in a quantitative indicator means a 20 percent or more change (either plus or minus) relative to the comparative baseline. If the expected change is less than 20 percent, the change is not considered to be significant. The same threshold is roughly used to assess changes in qualitative indicators (e.g., fishing vessel safety). However, whereas changes in quantitative indicators are based on model projections, predicted changes in qualitative indicators are based on the judgement of the socioeconomic analysts.

4.1.1.6 Ecosystem

Significance thresholds for determining the ecosystem-level impacts of fishing would involve both population-level thresholds that have already been established for species in the system (MSST for target species, and fishing-induced population impacts sufficient to lead to listing under the ESA or fishing-induced impacts that prevent recovery of a species already listed under ESA for nontarget species) and community or ecosystem-level attributes that are outside the range of natural variability for the system (Table 4.1-7). These community or ecosystem-level attributes are more difficult to measure directly and the range of natural variability of those attributes is not well known. We may also lack sufficient data on population status of target or non-target species to determine whether they are above or below MSST or ESA-related thresholds. Thus, indicators of the strength of fishing impacts on the system will also be used to evaluate the degree to which any of the alternatives may be having a significant ecosystem impact.

For each of the alternatives, the possible impacts on 1) predator/prey relationships, including introduction of non-native species, 2) energy flow and redirection (through fishing removals and return of discards to the sea), and 3) diversity will be addressed.

4.1.2 Data Gaps and Incomplete Information

The Council on Environmental Quality (CEQ) guidelines require that:

> When an agency is evaluating reasonably foreseeable significant adverse effects on the human environment in an environmental impact statement and there is incomplete or unavailable information, the agency shall always make clear that such information is lacking (40 CFR 1502.22).

The regulations instruct that where the information is relevant, but "the overall costs of obtaining it are exorbitant or the means to obtain it are not known" (40 CFR 1502.22), the following should be included in the EIS:

- A statement that such information is unavailable;
- a statement of the relevance of the information to evaluate reasonably foreseeable significant adverse impacts;
- a summary of existing information that is relevant to evaluating the adverse impacts; and

- the agency’s evaluation of adverse impacts based on generally-accepted scientific methods.

In the analysis, this Programmatic SEIS identified those areas where information is unavailable to support a thorough evaluation of the environmental consequences of the alternatives. Efforts have been made to obtain all relevant information; however, where data gaps still exist, the implication is that these areas qualify for the CEQ exemptions above.

As outlined in Section 4.1.1, the impact ratings used in this analysis include three categories that indicate a lack of complete data: unknown, conditionally significant adverse, and conditionally significant beneficial. In cases where these ratings are used, a discussion is included about the nature of the unavailable information and its relevance to this analysis. In cases where a ‘conditional’ qualifier is used, the analysts, using credible scientific methods, have based their assessment on existing information and specific assumptions based on professional judgement in order to evaluate the reasonably foreseeable adverse or beneficial impacts. Where ‘unknown’ is used, not enough baseline information exists to evaluate the impact of the alternatives; however, based on past management and scientific experience, an adverse effect is not foreseeable.

Section 5.1 catalogs the information that is unknown or unavailable for all resource categories. The section discusses ongoing and proposed research relating to the North Pacific groundfish fisheries, and lists the known data gaps for each resource category. Additionally, the specific research initiatives recommended in the various alternative policies are also identified.

4.1.3 Direct and Indirect Analysis

4.1.3.1 Target Species, Prohibited Species, Other Species, Forage Fish Species, Non-Specified Species

The impacts on target species, prohibited species, other species, forage fish species, and non-specified species were evaluated with respect to five effects: 1) fishing mortality, 2) change in biomass level, 3) spatial/temporal concentration of the catch, 4) prey availability, and 5) habitat suitability. Fishing mortality, biomass changes, and spatial/temporal concentration of the catch are considered direct effects as opposed to prey availability and habitat suitability which are considered indirect effects to target species. The significance of these effects was evaluated according to whether the impacts of effects, within the current fishery management regime, might be reasonably expected to jeopardize the sustainability of each target species or species group. Under FMP 1, all target categories are managed within the definitions of Amendments 56/56 to the BSAI and GOA FMPs, which set the overfishing levels and the maximum permissible acceptable biological catch for six tier designations as described in Appendix B. Under FMP 1, only one stock is designated as falling within Tier 1 (eastern Bering Sea [EBS] pollock), and no stocks fall within Tier 2. Of the 21 BSAI target groundfish categories, 11 species are managed under Tier 3, no species under Tier 4, eight species or species complexes are under Tier 5, and one species group (squid) under Tier 6. Of the 16 GOA target groundfish categories, eight species are managed under Tier 3, seven species or species complexes under either Tiers 4 or 5, and one species (Atka mackerel) under Tier 6. The significance of the effects of the current fishing mortality levels is evaluated with respect to the overfishing mortality rates as set forth in Amendments 56/56.

As a means of evaluating the intensity (significance) of the effects on target species under the alternatives, the following system was developed whereby the significance of the five selected effects was evaluated. Additional details for each species or species complex are given in its specific section. The system consisted of four rankings of significance including: “significant negative,” “unknown,” “insignificant” and “significant positive.” Recognizing that such general terminology is inherently subjective, we applied criteria where possible to define the terms and rankings. Where metrics were not available, descriptions of the impacts within the text are relied upon to justify the significance evaluation.

For the target species, the multi-species, multi-fisheries simulation projection model provided fundamental dynamics to the model behavior. That is, as the biomass of an FMP species changed in the future, the constraint (via acceptable biological catch/total allowable catch [ABC/TAC] control) also changed. The outputs from the model were primarily intended to reflect these dynamics and the interactions with the species composition of the different fisheries.

4.1.3.2 Habitat

MSA provisions call for the description of measures to avoid, mitigate, or offset adverse effects to EFH. EFH is defined in the MSA as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.” (16 U.S.C. 1802 3, 104–297). Consistent with these provisions, this analysis focuses on the following question: Do the alternative management policies result in conditions that offer protection to and minimization of adverse impacts to EFH? For Alaska groundfish, this includes the habitat for all target groundfish species, non-target species, prohibited species, other species, and their prey. When viewed in aggregate, across all species, EFH is all pelagic and benthic habitat in the Alaska Exclusive Economic Zone (EEZ). The EFH definitions for all managed species are currently being reviewed by the NPFMC and NOAA Fisheries through its EFH amendment process. A decision on the Alaska EFH definitions will be made by the end of 2004. For purposes of this Programmatic SEIS, we therefore provisionally defined EFH generally as all benthic habitat.

As explained above, this analysis focuses on benthic habitat, which is generally believed to be at greater risk to the impacts of fishing than non-benthic habitat in the water column. In addition, much of the analysis focuses on the impacts of bottom trawling. It is recognized that fixed gear (longlines, pots, and jigs) or pelagic trawl gear that comes in contact with the sea floor can disturb benthic habitat. In some types of habitat, fixed gear may cause an impact due to its ability to be more easily fished on rougher substrates (e.g., boulders with coral) than bottom trawl gear. However, most scientific studies of gear impacts have dealt with bottom trawls and dredging because this gear is the most controversial (Auster and Langton 1999, Jennings and Kaiser 1998, Hall 1999b, NRC 2002).

The impacts of bottom trawling on benthic habitat are described in Section 3.6.4. In general, relative to unfished habitat, areas fished with bottom trawls are expected to have reduced habitat complexity and species diversity, and changes in species composition. The level of habitat complexity depends on the structural components of the living and non-living benthic environment. Habitat complexity is reduced when epifauna that form structures are removed or damaged. Sedimentary bedforms are smoothed, and infauna that form burrows and pits are removed. Worldwide studies of the effects of bottom trawling have generally found that trawling reduces habitat complexity (Auster and Langton 1999). These findings have been confirmed by studies conducted in Alaska (Freese *et al.* 1999, McConnaughy *et al.* 2000). The extent of the impacts depends on many factors such as habitat type, natural disturbance, recovery rates, and the intensity and spatial distribution of bottom trawling.

Evaluating habitat impacts in marine fisheries is not a well developed field. We are aware of few, if any, applicable analytical methods and have had to develop methods ourselves as we prepared the Programmatic SEIS. It didn't seem reasonable then to rely on a single analytical tool when such tools are still being refined.

Specific impacts on habitat, as noted above in Section 4.1.1.2, are difficult to predict because the information needed to do so is generally incomplete for Alaskan waters. It may never be possible to fully and quantitatively account for all factors involved in determining how an ecosystem will respond to fishing activities.

However, we have analyzed the direct and indirect effects identified in Table 4.1-4 by using, to varying degrees, four primary sources of information:

1. Estimates of the bycatch of living habitat derived from the multi-species projection model described in Section 4.1.5;

2. the results of a habitat impacts model (Fujioka 2002, Rose 2002) for estimates of the equilibrium levels of biostructure;

3. estimates of the amount of area by habitat type and geographic zone closed year round to bottom trawling for all species; and

4. evaluation of the spatial distribution of bottom trawl closures relative to fishing intensity and habitat types.

We want to emphasize that while the multi-species model, habitat impacts model, and estimates of the amount of area by habitat type closed year round were used initially, these information sources later became peripheral to the habitat impacts analysis. The multi-species projection model was used by Programmatic SEIS analysts as a tool to determine impacts of the alternatives in future years. These data were obtained from the NMFS observer program. For the most part we found that future projections of living habitat bycatch using these data and multi-species model results did not prove useful in analyzing habitat impacts as compared to target species and other fish species impacts. For example, the NMFS observer program aggregates all coral species into a single category. While these data are useful in documenting that these benthic organisms are taken as bycatch in various groundfish fisheries, problems arise due to the wide variety of coral species and the vulnerability of hard versus soft corals to different gear types. Differences in recovery rates among species make assessing fishing impacts on these species difficult. All corals likely provide an important biostructure component to EFH for some of the managed species.

In order to run the habitat impact model described by Fujioka (2002; see Section 4.1.6) for the various alternatives, reliable catch and effort projections are needed. For example FMPs where the illustrated closure scheme differs substantially from the baseline in the location and amount of areal closures and/or fishing effort (example FMP 2.1, FMP 3.2 and FMP 4.1), the resolution of the data needed to run the model was not available.

Estimates of the amount of area by habitat type and geographic zone closed year round to bottom trawling for all species refers to some simple calculations of the amount of area closed to bottom trawling. While we present this data in the Programmatic SEIS for information purposes, for the most part this information was used sparingly to rate the alternatives in terms of habitat impacts.

As a result of these data limitations, our analysis relied most heavily on a qualitative approach a comparison of maps of fishing intensity [presented by C. Rose (2002) at the Effects of Fishing Symposium] and closure area illustrations developed by the project team. This qualitative approach was an important part of the Programmatic SEIS analysis. Analysts would have liked to have conducted a more quantitative analysis of the spatial distribution of proposed closures relative to fishing intensity; however, there was only sufficient time to apply the data quantitatively to the status quo FMPs (e.g. example FMP 1), relying on our qualitative judgment in evaluating the other alternatives. Since then, quantitative analyses corroborate our qualitative judgments: that closing significant proportions of heavily fished areas would likely require increased fishing effort to maintain current harvest levels and would therefore result in little decrease, if any, in overall impact levels. (Alternatives that close only unfished or lightly fished areas reduce impact levels but do not address the concern about impacts in the heavily fished areas.)

This analysis does not include impacts to the effects on non-living habitat, such as boulders, cobbles and sandwaves which can be disturbed by bottom trawls (Auster and Langton 1999). In most cases the structural integrity, and hence the complexity of the habitat would not be greatly reduced, but when nonliving substrates are disturbed, the organisms living on them may die or be damaged.

Living Habitat – Direct Mortality of Benthic Organisms

Living habitat includes organisms that provide high microhabitat complexity, which serves as cover for fish and their prey. These living habitats include: corals, sponges, anemones, sea whips, sea pens, and tunicates. Criteria to determine acceptable levels of mortality to living habitat have not been established. Such criteria would need to consider fishing induced mortality relative to such characteristics as natural mortality, fecundity, abundance, growth rates, and recruitment. Many deep water areas are characterized as stable environments dominated by long-lived species. In such areas the impacts of fishing can be substantial and long term (Auster and Langton 1999). Species such as red tree coral (Primnoa) are very long lived (more than 100 years old) and slow growing, and the habitat they provide does not easily recover if damaged by fishing (Risk *et al.*1998, Andrews *et al.* 1999, Krieger and Wing 2000). Recent studies also indicate long recovery rates for deep water sponges that have been damaged or removed by trawling (Freese 2003). A potential quantifiable measure of the expected impact to such habitat are estimates of their living habitat bycatch derived from the multi-species projection model described in Section 4.1.5. Observer data from 1999 to 2001 provides information to estimate baseline levels of this bycatch (Tables 4.1-8 and 4.1-9). For the most part we found that projections of bycatch of living habitat from the multispecies projection did not provide realistic data to rate alternatives. Thus we relied more heavily on application of the habitat impacts model (see Section 4.1.6) as the tool to assess changes to direct mortality of benthic organisms.

There is also unobserved mortality and damage to living habitat that would not be reflected as bycatch (Freese *et al.* 1999, Krieger and Wing 2000, Freese 2003). Assuming that most living habitat caught as bycatch dies, then observed bycatch is a minimum estimate of fishing-induced mortality. We caution about comparing bycatch across gear types and fisheries. For example, if a particular fishery tends to catch more living habitat, this could indicate more impact for that fishery. However, there is little or no information to compare impacts between different gear types. Additionally, one gear type may be particularly efficient at catching and retaining an organism relative to the impact it has on living habitat, while another gear type may not retain the organism while causing a different level of impact. Such variability makes assessing fishing impacts very challenging and as a result, this has been prioritized for research.

Criteria to determine acceptable levels of mortality to living habitat have not been established. Such criteria would need to consider fishing induced mortality relative to such characteristics as natural mortality, fecundity, abundance, growth rates, and recruitment. Many deep water areas are characterized as stable environments dominated by long-lived species. In such areas the impacts of fishing can be substantial and long term (Auster and Langton 1999). Species such as red tree coral (Primnoa) are very long lived (more than 100 years old) and slow growing, and the habitat they provide does not easily recover if damaged by fishing (Risk *et al.*1998, Andrews *et al.* 1999, Krieger and Wing 2000). Recent studies also indicate long recovery rates for deep water sponges that have been damaged or removed by trawling (Freese 2003).

Benthic Community Diversity and Geographic Diversity of Impacts

Closed areas can protect living habitats from damaged by fishing activities. In addition, closed areas can promote recovery in habitats already impacted by fishing. Ideally placement of the closed areas would occur across a range of vulnerable, representative habitat types (NRC 2002). Areas seasonally closed to particular fisheries may afford limited protection to EFH. For example, in the current BSAI and GOA FMPs, seasonal closures to Pacific cod, Atka mackerel, and pollock fishing exist in areas of sea lion foraging. These closures, however, provide little protection to EFH because they are either fished seasonally and/or allow fisheries for other species. Thus, they address sea lion concerns but fail to address the need to fully protect EFH. Only year round closures for all species are considered to provide protection to EFH.

Simple calculations of the amount of area by habitat type and geographic zone closed to bottom trawling may provide some data to rate alternatives. However this data does not provide information on the spatial distribution of closures relative to fishing intensity. Thus area calculations are mostly provided for information purposes.

Consideration must also be given to the geographic distribution of fishing intensity relative to closures. For instance, if closures are placed primarily in areas where there is little or no fishing then there will be little benefit to habitat over baseline levels. In contrast, if closures are placed primarily in fished areas that have high fish density and the displaced fishing effort moves to areas of low fish density, the result may be more habitat damage because greater effort may be required to catch the same amount of fish. Consideration of the geographic distribution of impact levels allows the habitat unit's distance and direction from other habitat, geographic, and oceanographic features to be accounted for.

We were able to apply the habitat impacts models to status quo FMPs (example FMP 1) to quantitatively assess these direct effects. However for the other alternatives we had to rely on a more qualitative approach. Thus we used maps of baseline fishing intensity (Rose and Jorganson 2002) and maps alternative specific closure areas to assess changes to benthic community diversity and geographic diversity of impacts.

Given little is known about the habitat requirements of target, prey, or predator species in the BSAI and GOA and the location of specific habitats in these regions, managers must ask what is the best strategy for distributing fishing impacts over the potential fishing grounds? Should effort be distributed uniformly over the fishing grounds, or should effort be concentrated in certain areas while leaving other areas unfished? If so, how large and in what orientation should the fished or unfished areas be? One may theorize that vast expanses of contiguous fishing effort or impact levels should be avoided. The evaluation of fishing impacts of example FMPs in this Programmatic SEIS operates under the following assertions and assumptions:

1. Knowledge about habitat value as EFH and its distribution is of low resolution based on gross bathymetric information, such as shelf, slope, gullies, or large scale geographic or oceanographic features and we assume that such features capture EFH.

2. Relative to habitat distribution, spatially diverse or patchy fishing impacts are preferable to uniformly distributed impacts (Duplisea *et al.* 2002). Thus, one of the criteria used to evaluate the alternatives will be the spatial and geographic diversity of fishing impacts. The patchiness of fishing effort may be enhanced by having some areas not fished dispersed within historically fished areas. This patchiness promotes habitat diversity.

3. Geographic diversity of impacts and protection is obtained by having a consistent pattern of varying levels of impact within a habitat type. This would be achieved most simply by establishing long term closure areas over a portion of each habitat type within fished areas. Totally encompassing within a closure the habitat type or the cluster of historical fishing intensity would not achieve a diverse impact.

4. Bathymetric features such as gullies, banks, shelf, slope, and slope/gully intersections represent individual general habitat types. In addition clusters of fishing intensity represent an area of unique habitat, perhaps defined only in part by benthic habitat. In the GOA the spatial resolution of these habitat types is on a much finer scale than the fairly uniform bathymetry of the Bering Sea. Habitat types in the Aleutian Islands are not as easily classified or distinguished and are on an even finer spatial resolution.

4.1.3.3 Seabirds

Because of differences in foraging behavior, abundance, and distribution, some bird species are more likely to be directly or indirectly affected by the groundfish fishery than others. Direct effects are those which take place at the same time and place as the fishing activity. Indirect effects are removed in time and/or space from the initial action. The mechanisms and history of direct and indirect effects of fisheries on seabirds are described in Section 3.7.1, along with other natural and human-caused influences on these effects. Details on the extent of each type of effect for each species, to the extent that they are known, are presented in the species accounts of Section 3.7.

For purposes of this chapter, some types of potential effects offer clearer comparisons of the alternatives. than others. For seabirds, one direct effect (mortality) and two indirect effects (prey availability and benthic habitat) were analyzed to make the distinction between alternatives. Data on incidental take come from the North Pacific Groundfish Observer Program and include birds that are killed or seriously injured in fishing gear or by striking the vessel or its rigging. Both indirect effects involve changes in the food supply of birds, but the mechanisms are different. “Prey availability” involves the removal of prey, and competitors for that prey, from the water column. “Benthic habitat” describes changes in the physical and biotic structure of the ocean bottom that potentially affect the capacity of that habitat to support the food web important to seabirds. Consumption of fishery wastes has implications for both incidental take (serving as an attractant to vessel interactions) and food availability. Since incidental take is addressed in different ways by the different alternatives, and the production of fishery wastes is closely linked to overall TAC, consumption of fishery wastes will be incorporated into the analysis of effects on prey availability, which is also related to fishing effort. The effects on benthic habitat are analyzed separately because they are more defined in space and the alternatives vary considerably and specifically with fishing area closures.

Other potential effects, such as oil spills, plastic pollution, and introduction of nest predators, are the result of vessel traffic rather than fishing effort. An oil spill from a shipwrecked fishing vessel or the accidental release of rats from a ship to a seabird colony could have very substantial repercussions for one or more seabird species. However, the magnitude of the effect will depend on a host of variables that cannot be predicted. In addition, the risks of these types of events occurring are not necessarily proportional to fishing effort. Even the closure of the fishery would not eliminate these risks because the fishing and processing vessels would likely be used in other fisheries or brought to port where they may actually increase the risk of an effect (i.e., introduction of nest predators). Because these types of effects do not lend themselves to distinguishing between the alternatives, they will not be analyzed in the direct/indirect effects of each FMP. However, they are important to the overall effects of the fishery and are included as part of the baseline condition and as contributions to the cumulative effects.

Significance criteria were based on whether the proposed action would be likely to result in population level effects, which are defined as changes in the population trend outside the range of natural fluctuations (see Section 4.1.1 for further details). The projection model was used for predictions of fishing effort under the different FMP bookends, especially with respect to different gear types. The analysis also includes other factors such as spatial/temporal restrictions and potential gear modifications for seabird avoidance. However, because there are a large number of unpredictable variables and gaps in our knowledge about the natural history and populations of particular species, as well as many kinds of ecosystem effects, it was impossible to ascertain significance on a strictly quantitative basis. Conclusions are based on professional judgements of pertinent data, literature review, and the likelihood of certain conditions occurring.

4.1.3.4 Marine Mammals

Effects of the groundfish fishery management alternatives on marine mammals will be examined by focusing analyses around four core questions which were modified from Lowry (1982):

1. Is the alternative management regime consistent with efforts to avoid direct interactions with marine mammals (incidental take and entanglement in marine debris)?

2. Does the alternative management regime result in fisheries harvests on prey species of particular importance to marine mammals, at levels that could compromise foraging success (harvest of prey species)?

3. Does the alternative management regime result in temporal or spatial concentration of fishing effort in areas used for foraging by marine mammals (spatial/temporal concentration of removals with some likelihood of localized depletion)?

4. Does the alternative management regime modify marine mammal or forage behavior to the extent that population level impacts could occur (disturbance)?

The existing environmental conditions under and independent of the 2002 fishery management measures were used as the baseline for comparing the alternatives with respect to effects on marine mammals, as expressed by the above questions. The expected effects of each alternative were compared to the effects as they exist under the baseline conditions to determine the relative significance of the impacts on marine mammals.

Direct Effect – Incidental Take/Entanglement in Marine Debris (Question 1)

Groundfish fisheries directly affect marine mammals when animals are incidentally caught or become entangled in fishing gear. When animals are incidentally taken or entangled, serious injury or mortality may or may not result. Some species are more susceptible than others to interactions with fishing gear depending on the extent of spatial overlap with the fisheries and on their ability to detect and avoid gear. Fishery/marine mammal encounters which result in high levels of mortality and serious injury may have the potential to cause population level effects. The level of incidental take and entanglement which results in population level effects will vary according to the status and trajectory of each stock.

The MMPA requires that take of ESA or MMPA listed marine mammals incidental to commercial fisheries be authorized under a 101 a (5)(E) permit upon determination that the incidental mortality and serious injury from these fisheries will have a negligible impact on the species or stock. For most activities, a negligible impact is defined as having a duration and intensity which results in an insignificant effect on the population. For fishing activities, the intensity of the effect is a more important consideration than the duration of the effect. If an impact is expected to cause no more than a 10 percent delay in recovery of an ESA or MMPA listed species, then the impact is deemed to be negligible and would thus be insignificant. If incidental take and entanglement in fishing gear is expected to occur at a level which would delay recovery of a stock by more than 10 percent than would be expected under baseline conditions, the impact will be significant. This approach allows for the incorporation of parameters specific to each population and thus accounts for the variable effects of incidental take according to the status and trajectory of each stock.

To calculate the delay in recovery imposed by additive mortality and injury incidental to fishing operations, definitions of the following are needed: the point at which the population is considered to be recovered, the current population size, and the intrinsic rate at which the population is increasing. For species with increasing population trajectories it is possible to estimate the time until the population will be recovered. For species with negative population trajectories (declining stocks), the time period over which the population would be expected to go extinct can be estimated. If the additional mortality and serious injury resulting from incidental takes in commercial fisheries does not accelerate the estimated time to extinction by more than 10 percent, the impact will be determined to be negligible at the population level, thus rendering it "insignificant" for purposes of this analysis.

Under the best case scenario incidental take and entanglement of marine mammals in fishing gear would be zero animals, yet even under this scenario the population effect on the species would be insignificant, therefore effects ratings of (conditionally) significant beneficial are not applicable to this analysis.

Direct/Indirect Effect – Harvest of Key Prey Species (Question 2)

Direct and indirect interactions between marine mammals and groundfish fisheries occur due to overlap in the size and species of groundfish harvested in fisheries that are also important prey for marine mammals, and due to the spatial/temporal overlap in marine mammal foraging and commercial fishing activities. By design, fishing significantly reduces the spawning biomass of harvested species from an "unfished" level to a "fished" level. The relevant question is whether fishing under these global (e.g., large scale such as BSAI or GOA wide) exploitation strategies reduces the environmental carrying capacity of marine mammals by affecting the prey field on which they depend for survival.

Fishery removals of marine mammal prey items may affect the resource such that food availability becomes the limiting factor regulating the size of the marine mammal population. If fisheries remove more of a prey species' standing biomass than is required to maintain a marine mammal population at the current size, the fishery would be deemed to result in a significant adverse effect at the population level. Alternately, if a fishery management regime is expected to increase the available standing biomass of a prey species to a level such that the population size and/or health is expected to increase, the fishery would be deemed to result in a significant beneficial effect at the population level.

To assess the point at which the alternate fishery regimes affect the availability of key prey species relative to the baseline such that marine mammals experience population level effects, it is necessary to know: the marine mammal's energy requirements; the relative contribution of each prey species to those energy requirements; the adequacy of the existing standing biomass of prey; the standing biomass of the prey species before and after the fishery; and how the change in the standing biomass equates to changes in the marine mammal population's vital rates or carrying capacity. With the best available scientific and commercial data, our current understanding of marine mammal bioenergetic requirements does not warrant such a determination.

Due to the limited state of knowledge regarding the effects of the harvest of marine mammal prey species, we relaxed the requirement that varying levels of fishery removals be directly linked to effects which would be detectable at the population level. The significance criteria for this category of effects was selected to allow for informative comparisons of each fishery management alternative relative to the baseline. A 20 percent change in the fishing mortality rate, relative to the baseline, was selected as the significance threshold as it was judged to result in large enough changes to the prey field such that significant impacts on marine mammal populations would reasonably be expected due to changes in the standing biomass of their key prey. Scenarios in which the fishing mortality rate (*F*) of key prey species is projected to increase by at least 20 percent were determined to have significant adverse effects on marine mammals, whereas a decrease in F of at least 20 percent was determined to have a significant beneficial effect. The effect of harvest of prey species was determined to be unknown when there was insufficient diet information for a given marine mammal species to determine if there would be overlap with the fisheries.

Indirect Effect – Spatial/Temporal Concentration of the Fishery (Question 3)

Overall effects of fisheries on marine mammal populations vary according to the spatial/temporal execution of the fishery. Although global fishery removals are designed to be precautionary such that the productivity of target stocks and their ability to support natural predators are not compromised, fisheries compete with marine mammals when these removals are concentrated such that the resource becomes limited in the times and locations where fisheries and marine mammals overlap. The intensity of the effects on marine mammals will vary according to the extent of competition (amount of overlap and degree of resource limitation) and the importance of the resource to marine mammals in a particular season or area. Because it is not possible to quantify the amount of competition between fisheries and marine mammals, nor to state the level of competition that results in changes at the population level, the effects of spatial/temporal fishing concentrations under the various alternatives were assessed qualitatively according to the spatial and seasonal foraging requirements of marine mammals. Relative to the fishery distribution under the rules and regulations in effect for 2002 (the baseline condition), alternatives were categorized as having significant adverse effects on marine mammal populations if there was “much more spatial/temporal concentration” in important foraging habitat and/or critical periods and significant beneficial effects if there was “much less” concentration of the fishery in key areas and seasons. “Unknown” was used when there was insufficient information to determine what constitutes the key areas and seasons for a given marine mammal species.

Direct Effect – Disturbance (Question 4)

Activities related to groundfish fisheries in the BSAI and GOA have the potential to affect marine mammal behavior. Disturbance to marine mammals may result from vessel traffic, fishing operations, or underwater noise such that otherwise “normal” behavior or movement patterns are altered. As defined here, these disturbances have significant adverse effects on marine mammal populations when marine mammal or forage behavior is modified to the extent that population level impacts could occur. Because it is not possible to quantify disturbance resulting from fisheries, nor to state the level of disturbance that results in changes at the population level, the level of disturbance expected to occur under the various alternatives was compared qualitatively to the baseline level of disturbance to evaluate the significance of the alternatives. The effects analysis for this category incorporated projections from the multi-species management model to determine changes in fishery patterns and information on marine mammal distributions and behavior to infer potential disturbance levels. The significance criterion was similar to that for evaluating fishery concentrations in time and space with “much more” or “substantially more” disturbance leading to a “significant adverse” finding. “Insignificant” was used for those species that do not appear to be disturbed by fishing vessels and in cases where the level of disturbance was not expected to fluctuate to a large degree relative to the baseline. Under the best case scenario disturbance of marine mammals resulting from groundfish fishing activities would be zero, yet even under this scenario the population effect on the species would be insignificant, therefore effects ratings of (conditionally) significant beneficial are not applicable to this analysis. “Unknown” was used when there was insufficient information to determine what constitutes disturbance for the species.

Marine Mammal Species and Species Groups

The effects of the alternative FMPs were analyzed on either individual species/stocks of marine mammals or on aggregate groupings of marine mammals according to the level and intensity of the expected effects or according to the status of the marine mammal stock. Species or stocks analyzed individually include: the western stock of Steller sea lions, the eastern stock of Steller sea lions, northern fur seals, harbor seals, transient killer whales, and sea otters. Marine mammals analyzed in aggregate include the "other" pinnipeds, toothed whales (including resident killer whales), and baleen whales occurring in the environment affected by the BSAI and GOA groundfish fisheries. Western and eastern Steller sea lion stocks were split in the analysis due to the differences in their population trajectories, ESA listing status, and degree of overlap with groundfish fisheries. Northern fur seals and harbor seals were broken out from the "other pinnipeds" as they are expected to be more affected, directly or indirectly, by groundfish fisheries than the other pinniped species in the affected area. Transient killer whales were split out from the "other toothed whales" as their diets differ substantially from the other species in this category.

4.1.3.5 Socioeconomic Effects

Assessment of socioeconomic impacts considers important factors including:

- Impacts on harvesting and processing sectors, including 1) catcher vessels (CVs), 2) catcher processors (CPs), and 3) inshore processors and motherships; using catches of all groundfish species, groundfish ex-vessel value and product value, groundfish employment and payments to labor, excess capacity, product quality, product utilization rates, average costs, and fishing vessels safety as variables.
- Regional impacts, on six regions (Alaska Peninsula and Aleutian Islands, Kodiak Island, Alaska Southcentral, Southeast Alaska, Oregon coast, Washington Inland Waters), using processing, harvesting, payments to labor, and employment variables.
- Community Development Quota (CDQ)-related impacts, including changes to the CDQ program and changes to the CDQ species TACs.
- Subsistence-related impacts on groundfish, Steller sea lion and salmon subsistence, as well as opportunities for practicing subsistence.
- Environmental justice impacts resulting from changes in fishing activity, or impacts to the CDQ program or subsistence.
- Impacts on consumer benefits (U.S. consumers of groundfish products).
- Impacts on benefits from marine ecosystems (other than those benefits related to commercial groundfish fisheries) including non-market (existence value and option value, etc.) and other uses of the ecosystem such as recreational fishing or tourism.

The socioeconomic impacts of the alternatives have been assessed using the "Sector Model" to estimate catch and processing amounts and revenues for the fishing and processing sectors and regions described in Section 3.9.2. The Sector Model uses output from the multi-species management model, combined with the historical harvest and processing proportions, to estimate the distribution of catch and processing among the various sectors and regions that rely on the groundfish fishery.

The Sector Model is a three-step process that:

1. estimates total catch and deliveries to processors;

2. proportions out deliveries to specific catcher vessel sectors; and
3. distributes catches and processing amounts among the various regions where processors are located or vessels are owned.

In each step of the Sector Model, the catch of each species by gear and subarea is distributed to successive sectors based on the historical distribution from 2001 (the baseline condition for socioeconomic effects). The model and analytical framework used in the analysis for the harvesting and processing sectors are described in Section 4.1.7.

4.1.3.6 Ecosystem

Ecosystems consist of populations and communities of interacting organisms and their physical environment that form a functional unit that have some characteristic trophic structure and material cycles (i.e., how energy or mass moves among the groups). Fishing has the potential to influence ecosystems in several ways. Fishing may alter the amount and flow of energy in an ecosystem by removing energy and altering energetic pathways through the return of discards and fish processing offal back into the sea and through unobserved mortality of organisms not retained in the gear. The recipients, locations, and forms of this returned biomass may differ from those in an unfished system. Selective removal of species and/or sizes of organisms that are important in marine food web dynamics such as nodal prey species or top predators has the potential to change predator/prey relationships and community structure. Removals concentrated in space and time may impair the foraging success of animals tied to land such as pinnipeds or nesting seabirds that may have restricted foraging areas or critical foraging times that are key to survival or reproductive success. Introduction of non-native species may occur through emptying of ballast water or introduction of hull-fouling organisms from ships from other regions (Carlton 1996). Introductions of such species have the potential to cause large changes in community dynamics. Fishing can alter different measures of diversity. Species level diversity, or the number of species, can be altered if fishing essentially removes a target or nontarget species from the system. Fishing can alter functional diversity if it selectively removes a trophic or other type of functional guild member and changes the evenness with which biomass is distributed among a trophic guild. Fishing gear may alter bottom habitat and damage benthic organisms and communities that serve important functional roles as structural habitat or trophic roles. Fishing can alter genetic level diversity by selectively removing faster growing fish or removing spawning aggregations that might have different genetic characteristics than other spawning aggregations.

A great deal of literature has been written on possible indicators of ecosystem status in response to perturbations (e.g., Odum 1985, Pauly *et al.* 1998, Rice and Gislason 1996, Murawski 2000). These indices can show changes in energy cycling and community structure that might occur due to some external stress such as climate or fishing. For example, fisheries might selectively remove older, more predatory individuals. Therefore, we would expect to see changes in the size spectrum (the proportion of animals of various size groups in the system), mean age, or proportion of r-strategists (faster growing, more fecund species such as pollock) in the system. These changes can increase nutrient turnover rates because of the shift towards younger, smaller organisms with higher turnover rates. Total fishing removals and discards also provide a measure of the loss and re-direction of energy in the system due to human influences. Total fishing removals relative to total ecosystem energy could indicate the importance of fishing removals as a source of energy removal in an ecosystem. Changes in scavenger populations that show the same direction of change as discards could be an indicator of the degree of influence discards have on the system. Discards as a proportion of total natural detritus would also be a measure that could indicate how large discards are relative to other natural fluxes of dead organic material. Levels of total fishing removal or fishing effort could also indicate the potential for introduction of non-native species through ballast water in fishing vessels. Fishing practices can selectively remove predators or prey. Tracking the change in trophic level of the catch may provide information about the extent to which this is occurring (e.g., Pauly *et al.* 1998). Thus, we will use measures of total catch, total discard, and information about the changing mean size of organisms to indicate the potential of each of the alternatives to impact ecosystem energy flow and turnover.

Total catch and trophic level of the catch will also provide information about the potential to disrupt predator/prey relationships through introduction of non-native species or fishing down the food web through selective removal of predators, respectively. Pelagic forage availability will be measured quantitatively by looking at population trends of pollock and Atka mackerel, target species that are key forage for many species in the BSAI and GOA. Bycatch trends of nontarget species such as the managed forage species group and herring will also be used as indicators of possible fishery impacts on those pelagic forage groups. Angermeier and Karr (1994) also recognized that an important factor affecting the trophic base is spatial distribution of the food. The potential for fishing to disrupt this spatial distribution of food, which may be particularly important to predators tied to land, will be evaluated qualitatively to determine the degree of spatial/temporal concentration of fishery removals of forage. We will evaluate these factors to determine the potential of each of the alternatives to disrupt predator/prey relationships.

The scientific literature on diversity is somewhat mixed about what changes might be expected due to a stressor. Odum (1985) thought that species diversity (number of species) would decrease and dominance (the degree to which a particular species dominated in terms of numbers or biomass in the system) would increase if original diversity was high while the reverse might occur if original diversity was low. Significance thresholds for species level diversity due to fishing are catch removals high enough to cause the population of one or more target or nontarget species to fall below minimum biologically acceptable limits: either MSST for target species, one that would trigger ESA listing, or that would prevent recovery of an ESA-listed species. Genetic diversity can also be altered by humans through selective fishing (removal of faster growing individuals or certain spawning aggregations). Accidental releases of cultured fish and ocean ranching tends to reduce genetic diversity (Boehlert 1996). Significance thresholds for genetic diversity impacts due to fishing would be catch removals high enough to cause a change in one or more genetic components of a target or non target stock that would cause it to fall below minimum biologically acceptable limits (MSST for target species, ESA listing or non recovery of ESA listed species. More recently, there is growing agreement that functional (trophic or structural habitat) diversity might be the key attribute that lends ecosystem stability (see review by Hanski 1997). This type of diversity ensures there are sufficient number of species that perform the same function so that if one species declines for any reason (human or climate-induced), then alternate species can maintain that particular ecosystem function and we would see less variability in ecosystem processes. However, measures of diversity are subject to bias, and we do not know how much change in diversity is acceptable (Murawski 2000). Furthermore, diversity may not be a sensitive indicator of fishing effects (Livingston *et al.* 1999, Jennings and Reynolds 2000). Nonetheless, we will evaluate the possible impacts that the alternatives may have on various diversity measures.

Quantitative measures of some of the indicators mentioned above have been identified for each of the alternatives. These include total catch, trophic level of the catch, total discards, total groundfish biomass, trophic level of groundfish biomass, and bycatch amount of forage, top predator species, habitat area of particular concern (HAPC) biota for the BSAI and GOA. We will address for each of the alternatives the possible impacts on 1) predator/prey relationships, including introduction of non-native species, 2) energy flow and redirection (through fishing removals and return of discards to the sea), and 3) diversity.

4.1.4. Cumulative Effects Methodology

4.1.4.1 Introduction

Analysis of the potential cumulative effects of a proposed action and its alternatives is a requirement of the NEPA. An environmental assessment or environmental impact statement must consider cumulative effects when determining whether an action significantly affects environmental quality. The CEQ guidelines for evaluating cumulative effects state that "…the most devastating environmental effects may result not from the direct effects of a particular action but from the combination of individually minor effects of multiple actions over time" (CEQ 1997).

The CEQ regulations for implementing NEPA define cumulative effects as:

> "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7).

Cumulative effects are linked to incremental actions or policy changes that individually may have small outcomes, but that in the aggregate and in combination with other factors can result in greater effects in the human environment of the BSAI) and GOA. At the same time, the CEQ guidelines recognize that it is not practical to analyze the cumulative effects of an action on the universe but to focus on those effects that are truly meaningful.

The cumulative effects analysis assesses the potential direct and indirect effects of groundfish FMP policy alternatives in combination with other factors that affect physical, biological, and socioeconomic resource components of the BSAI and GOA environment. Peer reviewed literature and quantitative research on the cumulative effects of fishing activities in the Bering Sea and GOA are limited. The cumulative effects analysis presented for each of the FMP policy alternatives addresses the potential magnitude of effects and is somewhat qualitative in nature.

The intent of the cumulative effects analysis is to capture the total effects of many actions over time that would be missed by evaluating each action individually. A cumulative effects assessment describes the additive and synergistic result of the actions proposed in this Programmatic SEIS as they interact with factors external to those proposed actions. To avoid the piecemeal assessment of environmental impacts, analysis of cumulative effects were included in the 1978 CEQ regulations, which led to the development of the CEQs cumulative effects handbook (CEQ 1997) and federal agency guidelines based on that handbook (e.g., EPA 1999). Although predictions of direct effects of individual proposed actions tend to be more certain, cumulative effects may have more important consequences over the long term. The possibility of these "hidden" consequences presents a risk to decision makers, because the ultimate ramifications of an individual decision might not be obvious. The goal of identifying potential cumulative effects is to provide for informed decisions that consider the total effects (direct, indirect, and cumulative) of alternative management actions. This section characterizes the incremental cumulative effects that potentially arise from external factors in combination with the direct and indirect effects.

4.1.4.2 Methodology

The methodology for cumulative effects analysis in this Programmatic SEIS consists of the following steps:

- *Identify characteristics and trends within the affected environment that are relevant to assessing cumulative effects of the FMP policy alternatives, including lingering effects and how they have contributed to the comparative baseline.* This information is presented in Chapter 3 of this Programmatic SEIS and summarized in the cumulative effects sections for each of the alternatives.

- *Describe the potential direct and indirect effects of each of the four FMP policy alternatives.* This information is presented in detail in Sections 4.5 through 4.9 of this Programmatic SEIS, and is summarized in the cumulative effects ranking tables. The cumulative effects analysis uses the specific direct and indirect effects that have been evaluated for comparison with external factors.

- *Identify past, present and reasonably foreseeable external factors such as other fisheries, other types of human activities, and natural phenomena that could have additive or synergistic effects.* Past actions must be evaluated to determine whether there are lingering effects that may still result in synergistic or incremental impacts when combined with the proposed action alternatives. The CEQ guidelines require that cumulative effects analysis assess reasonably foreseeable future actions. Because analysis of relevant past present and future effects depends on the resource or characteristic being evaluated, the time period for looking at past and reasonably future effects will vary. Both past BSAI and GOA FMP amendments and pertinent external factors used to evaluate potential effects are described further in this introduction.

- *Use cumulative effects tables to screen all of the direct/indirect effects with external factors to capture those synergistic and incremental effects that are potentially cumulative in nature.* Both adverse and beneficial effects of external factors on the criteria used for direct and indirect effects are assessed, and then evaluated in combination with the direct and indirect effects to determine if there are cumulative effects.

- *Evaluate the significance of the potential cumulative effects using criteria established for direct and indirect effects and the relative contribution of the action alternatives to cumulative effects.* Of particular concern are situations where insignificant direct and indirect effects lead to significant cumulative effects or where significant external effects accentuate significant direct and indirect effects.

- *Discuss the reasoning that led to the evaluation of significance, citing evidence from the peer-reviewed literature and quantitative information where available.* As with direct and indirect effects, the term conditional significance has been used where conclusions of significance have been based on reasoned assumptions, and the term unknown is used where there is not enough information to reach a conclusion of significance.

The advantages of this approach are that it 1) closely follows CEQ guidance, 2) employs an orderly and explicit procedure, and 3) provides the reader with the information necessary to make an informed and independent judgment concerning the validity of the conclusions.

The CEQ (1997) has established step-by-step guidelines for conducting a cumulative effects analysis. The guidelines set forth eleven steps that can be classified into four basic stages: Scoping, Organizing, Screening, and Evaluating. Table 4.1-10 shows how the cumulative effects assessment for groundfish fisheries management was adapted to closely follow the CEQ guidelines.

4.1.4.3 Scoping

A historical review of the BSAI and GOA FMP amendments was conducted, looking at the intent and consequences of FMP amendments since 1980. This information was used to prepare the comparative baseline that is presented in Chapter 3 and summarized in Section 4.4. In addition to issues that were derived from the historical FMP amendment review, both the scoping process and public review of the first draft of the Programmatic SEIS identified issues to be addressed in the cumulative effects analysis. The scoping comments identified two major issues associated with analysis of potential cumulative effects: the consideration of the additive effects of management actions over time and also the cumulative effects of the management regime as a whole; and the consideration of impacts of natural events versus fisheries management on the ecosystem, including the human component (socioeconomic and subsistence) of fishing communities.

Public comments on the first draft of the Programmatic SEIS identified 15 themes associated with the scope and conclusions of the analysis of potential cumulative effects. Among the suggestions was that cumulative effects analysis use a different "baseline" to compare the alternatives than the status quo management system. A summary of these issues can be found in the Scoping Summary Report (NMFS 2000a) and Comment Analysis Report (Appendix G).

4.1.4.4 Additive and Cumulative Effects of Past FMP Amendments

The potential effects of the original BSAI and GOA FMPs and their amendments are difficult to substantiate quantitatively. Given the inherently large fluctuations that occur naturally in fish populations and the complexity of the North Pacific fishery, it is not feasible to identify biological responses to managerial decisions designed to fine-tune fishery harvests under the mandate of both preserving stocks and maximizing commercial exploitation. Intended and unintended socioeconomic effects on the fishing industries and regions and communities that participate in the groundfish fishery are easier to assess. The analysis of FMP amendments was used to develop the comparative baseline presented in Chapter 3 and summarized in Section 4.4, and to identify lingering effects to carry forward into the cumulative effects analyses in Sections 4.5 through 4.9. The detailed analysis of FMP amendments is presented in Section 3.11.

4.1.4.5 Identification of External Factors and Effects

A cumulative effects analysis takes into account the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions (40 CFR 1508.7). External factors play an important role in developing the comparative baseline used to evaluate the effects of the proposed action and its alternatives, and to identify present and reasonably foreseeable future actions that are relevant to the cumulative effects analysis. For the purposes of this Programmatic SEIS, the definition of external actions includes both human controlled events such as other fisheries, pollution and industrial development, and natural events such as disease, winter mortality, and short and long term climate change.

In order to ascertain the importance of the external impacts in the cumulative case, a comprehensive checklist was produced for each resource category (marine mammals, seabirds, target species, non-target species, prohibited catch species, habitat, socioeconomic characteristics, and ecosystem). Information presented in the checklists was obtained from reviewing environmental impact statements, reports and resource studies, and peer-reviewed literature. The identified external factors were discussed in meetings with staff of the NOAA Fisheries Alaska Fisheries Science Center (AFSC) to confirm accuracy, identify any effects that might have been missed, and explore pathways through which the external influences might act in an additive or interactive fashion with the alternatives to produce cumulative effects.

Within each resource checklist the effects were divided into the two main categories 1) human controlled events and 2) natural events. Due to inherent differences from biological resources and systems, external effects impacting the socioeconomic category were developed to consider different events and topics, or different aspects of the same event (for example, potential biological factors of other fisheries include disturbance and habitat damage, whereas potential socioeconomic factors include contribution of participation in other fisheries to the overall viability of fishing industry harvesters and processors). Table 4.1-11 summarizes the external effects that have been incorporated into the cumulative effects analysis.

4.1.4.6 Organizing the Cumulative Effects Analysis

Potential cumulative effects of each of the policy alternative FMPs are presented in Sections 4.5 through 4.9 of Chapter 4. For each of the alternatives, the analysis of cumulative effects follows the analysis of direct and indirect effects within the discussion of each of the major resource topics (e.g., Target Fish, Marine Mammals, Socioeconomic Characteristics). The structure of the cumulative effects analysis also parallels the direct and indirect effect analysis in the organization of the impact screening tables, in that the categories of effects evaluated for each of the direct/indirect analyses are used to organize the cumulative effects screening tables.

The categories of effects to be evaluated were developed jointly by analysts preparing the direct/indirect and cumulative effects analyses. These effects appear in the far left hand column of both the direct/indirect and cumulative effects matrices. This approach facilitates evaluating the additive and synergistic effects of the FMP policy alternatives with past FMP amendments and external effects. It also provides transparent logic for those reviewing the Programmatic SEIS.

4.1.4.7 Screening Potential Cumulative Effects

The screening process for the cumulative effects analyses consists of the following steps:

- identify the cause and effect relationships and incorporate them into the categories of effects to be evaluated for the direct/indirect and cumulative effects analyses;

- identify whether potential effects on a given resource from from past external actions remain and have a lingering effect on the resource that contributes to the significance of potential cumulative effects;

- identify potential effects on a given resource from both direct and indirect effects of the policy alternative FMPs and from present and reasonably foreseeable external actions; and

- develop and utilize matrices as the organizational structure to incorporate past effects, direct/indirect effects, and the potential effects of present and reasonably foreseeable events in evaluating the potential for and significance of cumulative effects.

As indicated above, parallel impact assessment tables or matrices, have been constructed to screen and evaluate both direct, indirect, and cumulative effects, and ensure that the evaluation is orderly and systematic. Each direct and indirect matrix scores the alternatives with respect to the impacts they could produce on the subject resource component. The range of scores includes insignificant, significant, conditionally significant, and unknown. A '+' or '-' is added to the significant or conditionally significant score to indicate a beneficial or adverse effect.

A second series of matrices was prepared for each resource component under each alternative. The cumulative effects matrices tabulate the external factors identified in the scoping process (columns) against the direct and indirect effects that had been identified. Under a single resource category (e.g., marine mammals), a separate cumulative effects matrix was prepared for each resource component (e.g., Steller sea lion, northern fur seal, harbor seal, etc.). The matrices include both beneficial and adverse environmental effects associated with past, present, and potential future management decisions related to the four policy alternatives. External effects that could function additively or interactively with the direct and indirect effects of the alternatives are organized into two major categories of (1) human controlled and (2) natural events.

4.1.4.8 Evaluating the Significance of Potential Cumulative Effects

The potential for cumulative effects and their significance was evaluated for the resources and characteristics of the human environment described in Chapters and 3 and 4. For biological, habitat and ecosystem resources and characteristics, significance criteria and thresholds take into account the geographic scope, population level implications, and regulatory aspects of potential effects. Significance criteria and thresholds for socioeconomic characteristics take into account the relative magnitude of change, the geographic distribution of effects, and the regulatory aspects of potential effects.

Table 4.1-12 is an example matrix to illustrate the approach taken to evaluate cumulative effects. Starting in the far left hand column, the category of effect used in both the direct, indirect, and cumulative effects analysis is presented, along with a significance rating for the direct and indirect effect. Any persistent past effects to be carried forward in the cumulative effects analysis are identified. Next, reasonably foreseeable future human controlled and natural effects are identified and briefly described, along with the nature of contribution to cumulative effects. Categories include potential adverse of beneficial contribution, not a contributing factor, and unknown. The direct and indirect, persistent past, and external effects are then integrated to determine whether there is a cumulative effects and its significance. The far right hand column summarizes the cumulative effect and whether it is significant, conditional significant, insignificant, or unknown. Several rules of logic are applied to the process. If the direct/indirect effect is unknown, it is not possible to determine the cumulative effect, which is also unknown. If there are no persistent past effects and there are no reasonably foreseeable future effects (not a contributing factor), then there are no cumulative effects for a specific effects category. The logic for applying ratings of conditional significance and unknown is the same for direct and indirect effects (see Sections 4.1.2 and 4.1.3). The cumulative matrix tables are supported by text that describes in more detail the persistent past effects, relevant external factors, and the logic in determining the significance of cumulative effects.

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4.1.5 Description of the Multi-Species Analytical Model and its Assumptions

4.1.5.1 Background

In the Draft 2001 Programmatic SEIS, simulation models were developed that evaluated individual stocks, independently as if each species could be caught separately from other species. The simulation model thus failed to reflect the multi-species character of nearly all Alaska groundfish fisheries, which catch a wide variety of species even when "targeting" a single species. This meant that in many cases, single-species simulations did a poor job of representing the likely consequences of alternative management scenarios. For this revised Programmatic SEIS, simulation models have been developed that reflect this multi-species nature of the fisheries and their management.

Current groundfish management in federal waters of Alaska consists of strict quota management for FMP managed species. These quotas are closely monitored based on high levels of observer coverage. As quotas are approached in a given year (with reserves set aside for bycatch in other fisheries) directed fisheries become closed. Prohibited Species Catch limits (PSCs) are also closely monitored and affect season length and area openings. These quotas and PSCs effectively become constraints for all groundfish fisheries operating in the GOA and BSAI regions. These constraints are established based on area-specific TACs. The TACs are derived from the NPFMC's annual recommendations for ABC levels. As a matter of policy, the NPFMC's TAC for a given species or species group has always been less than or equal to the ABC for that species. The resulting management system is one that strives to meet the objective of providing fishing opportunities subject to a large number of constraints. Analysis of this type of fisheries regime has been modeled using Linear Programming (e.g., Brown *et a*l. 1979, Siegel *et al.* 1979, and Murawski and Finn 1986). In this Programmatic SEIS we attempt to mimic management of complex interacting fisheries and their impact on GOA and BSAI living marine resources using a similar approach.

Simulating current groundfish management in the U.S. North Pacific economic zone involves considering interactions between a large number of species, areas, and gear types. These fisheries are managed subject to a large number of constraints (e.g., ABCs and prohibited species caps). Management decisions are based on expectations about the array of species likely to be captured by different gear types and the cumulative effect that each individual fishery has on the allowable catch of each individual species (or species group). The expectations of capture by different fisheries are based on historical catch data of each species within area and gear strata. The ABC constraints come from stochastic projections of future stock dynamics for each individual species. Given these constraints, the predicted catch for each example FMP is then computed from an inseason management model. This management model accounts for the technical multispecies-interactions of the groundfish fisheries (see Ackley 1995 for an example application of within-year patterns for the EBS fishery). Finally, the predicted catches are then fed back into the age-structured information for each species (to compute the correct fishing mortality level) and projected through each year. This provides a reasonable representation of the current fisheries management practice for dealing with the multispecies nature of bycatch in target fisheries. Fisheries are defined by distinct target species, gear type, and area. The optimal decision-making process (related to actual removals) was simulated using historical information on catch composition of these fisheries. A schematic of the modeling approach is presented in Figure 4.1-1.

This section begins with a description on how individual stocks are treated and projected into the future (including details on how the constrained optimization is used to mimic management) followed by a critique of the approach and assumptions. The subsequent section describes how catch estimates were derived followed by how specific alternatives were modeled (including the data that were used). This section then concludes with a brief description on how model results were applied in different resource categories (e.g., to assess the impact on marine mammals).

4.1.5.2 Methods

Treatment of Stocks

For the stocks with age-structure information, the model is very similar to those used for the stock assessments upon which ABC recommendations are currently based, and it contains features and assumptions common to many fishery population dynamics models. Parameters and other inputs were obtained for each stock, taken directly or inferred from the most recent Stock Assessment and Fishery Evaluation (SAFE) report or, in some cases, obtained from AFSC scientists. The simulations began with numbers at age in 2002, which were projected forward using a random recruitment simulator (Inverse Gaussian) and a fishing mortality rate defined by the FMP under consideration. Recruitments were drawn from a statistical distribution (described below) whose parameters consisted of maximum likelihood estimates obtained from the recruitments listed in the 2002 SAFE report. Recruitment estimates after 1978 were used to estimate distribution parameters. No serial correlation was assumed. The age of recruitment varied between stocks, corresponding to the minimum age used in the respective assessment models. For stocks where age-structure information is not available, yet ABCs are set, the model used the most recent estimates of ABC as the upper limit on total catch. The list of species considered for the BSAI and GOA are presented in Table 4.1-13. The actual age-structured data used for the analyses is available online at www.fakr.noaa.gov/sustainablefisheries/seis/data.

Projection Model

The following presents details on the steps of the projection simulations. A glossary of notation is provided at the end of this section for reference.

Step 1: Select the Catch Composition Array Appropriate for the Alternative

As presented below, separate hypothetical catch-composition arrays were developed for each alternative. A catch-composition array can be simply thought of as a table where the rows represent a specific fishery (defined by target species, area, and gear type) and the columns represent the catch by species group or stock (See www.fakr.noaa.gov/sustainablefisheries/seis/data).

Step 2: Project Recruitments for all Years and Simulations

Recruitment estimates for the years 1978-2001 (or the largest available subset thereof) were obtained from each of the respective 2002 stock assessments. For each stock, these recruitments were used to find maximum likelihood estimates for the inverse Gaussian distribution parameters. The distribution was parameterized such that one of the parameters represented the distribution mean. A recruitment time series was obtained for each simulation by drawing randomly from this parametric distribution.

Step 3: Estimate Actual Fishing Mortality Rates for the Initial Year

The steps in this part of the model are described below. Because the example FMPs were assumed not to take effect until after 2002, these steps were conducted only once, rather than separately for all eight FMPs. Compute the fishing mortality rate that would set catch equal to C_t by solving the following implicit equation:

$$C_{2002} = F_{2002} \sum_{a=1}^{n_{age}} \left[N_{a,2002} \left(\frac{1-\exp\left(-M_a - F_t \sum_{h=1}^{n_{gear}} s_{a,h} d_h\right)}{M_a + F_t \sum_{h=1}^{n_{gear}} s_{a,h} d_h} \right) \sum_{h=1}^{n_{gear}} w_{a,h} s_{a,h} d_h \right]$$

Step 4: Project Numbers-at Age for all Ages, Years, and Simulations

For each example FMP, 200 projection simulations were conducted. The projected numbers at age in each year were based on an annual feedback of "actual" catch obtained from the linear programming constrained optimization algorithm (hereafter referred to as the LP). The steps for these projections were (for a given species) were as follows:

1) Initialize the simulation index:

$$u = 0$$

2) Increment the simulation index:

$$u = u + 1$$

3) Initialize the time index:

$$t = 1$$

4) Compute numbers at age for initial year of simulation *u*:

$$N_{a,t,u} = R_{t,u} \qquad \text{for } a = 1, t = 1$$

$$N_{a,t,u} = n_a \qquad \text{for } a > 1$$

5) Set fishing mortality rate for initial year of simulation *u*:

$$F_{t,u} = F_{2002}$$

6) Increment time index:

$$t = t + 1$$

7) Compute numbers at age in year t of simulation *u*:

$$N_{a,t,u} = R_{t,u}, \quad R_{t,u} \sim \text{InvGaussian}\left(\beta, \gamma\right) \qquad \text{for } a=1,$$

$$N_{a,t,u} = N_{a,t-1,u} \exp\left(-M_a - F_{t-1,u} \sum_{h=1}^{n_{gear}} s_{a,h} d_h\right) \qquad \text{for } 1 < a < n_{age},$$

$$N_{a,t,u} = N_{a,t-1,u} \exp\left(-M_a - F_{t-1,u}\sum_{h=1}^{n_{gear}} s_{a,h}d_h\right) + N_{a-1,t-1,u} \exp\left(-M_{a-1} - F_{t-1,u}\sum_{h=1}^{n_{gear}} s_{a-1,h}d_h\right) \quad \text{for } a = n_{age,}.$$

9) Compute the ABC fishing mortality rate that establishes the TAC for year *t* of simulation *u*.

The appropriate fishing mortality rate was determined by the projection year and the relative spawning biomass of the stock as shown in the table below (B_{ref} corresponds to $B_{40\ percent}$ in all cases unless otherwise specified). F_{ref} corresponds to the fishing mortality specified as the F_{ABC} value.

Relative spawning biomass	Fishing mortality rate
$B_{t,u} < \alpha B_{ref}$	$F_{t,u}^{ABC} = 0$
$\alpha B_{ref} \le B_{t,u} < B_{ref}$	$F_{t,u}^{ABC} = F_{ref}\left(\frac{B_{t,u}}{B_{ref}} - \alpha\right)/(1-\alpha)$
$B_{ref} \le B_{t,u}$	$F_{t,u}^{ABC} = F_{ref}$

where $B_{t,u} = \sum_{a=1}^{n_{ages}} N_{a,t,u} m_a w_a \phi_{a,t,u}$ and $\phi_{a,t,u}$ is the total mortality rate between the beginning of the year and the time of spawning. The value of $B_{t,u}$ was computed iteratively (since it can be a function of fishing mortality). Note also that for some FMPs (described below) these rules change for some species. For a given FMP *i,* the fishing mortality is treated as a function of the F_{ABC} value:
$F_t^{Alt_i} = f\left(F_{t,u}^{ABC}\right)$ as specified by the FMP.

10) Compute the TAC value as annually varying limit on catch. For a given species and value of $F_t^{Alt_i}$ (for alternative *i*) the projection model computes the TAC used in the constraint as

$$TAC_t^{Alt_i} = \sum_{h=1}^{n_{gear}} \sum_{a=1}^{n_{age}} N_{a,t} w_{a,h} \frac{F_t^{Alt_i} s_{a,h} d_h}{F_t^{Alt_i} s_{a,h} d_h + M_a^p}\left[1 - e^{-F_t^{Alt_i} s_{a,h} d_h - M_a^p}\right].$$

11) Compute the actual catch, $C_{t,u}$, given the suite of constraints from the LP optimization (described below).

12) Solve for the fishing mortality rate $X_{t,u}$ that would set catch equal to $C_{t,u}$ in year *t* of simulation *u* (as estimated from the multi-species management constrained optimization problem described below and varies by FMP) by solving the following implicit equation:

$$C_{t,u} = X_{t,u} \sum_{a=1}^{n_{age}} \left[N_{a,t} \left(\frac{1-\exp\left(-M_a - X_{t,u}\sum_{h=1}^{n_{gear}} s_{a,h} d_h\right)}{M_a + X_{t,u}\sum_{h=1}^{n_{gear}} s_{a,h} d_h} \right) \sum_{h=1}^{n_{gear}} w_{a,h} s_{a,h} d_h \right]$$

13) Check to see if all years of simulation u have been completed, then continue as necessary:
If $t<n_{pro}+1$, return to (6)
If $t=n_{pro}+1$, end simulation u.

14) Return to (2) until all simulations are complete.

<u>Step 5: Store Stock Performance Statistics from the Above Projections</u>

A series of individual stock performance indicators (for species with age-structure results specified) were computed separately for each FMP and described as follows.

Total biomass in each year and simulation:

$$T_{t,u} = \sum_{a=1}^{n_{age}} N_{a,t,u} w_a$$

Spawning biomass and catch (as specified above) were stored for each species, year and simulation. Approximate confidence bounds were computed from the simulation output by simply ranking results from the simulations and computing the percentile values corresponding to the desired intervals (here taken as the 10^{th} and 90^{th} percentile). Also computed was the implied spawning biomass per-recruit (SPR) rate given the level of catch in a single year and simulation. For example, the theoretical percentage of unfished spawning output expected from a single recruit if fishing mortality were equal to the estimated fishing mortality over the life of the species.

Average age for each stock in the final projection year across all simulations was also computed as:

$$A = n_{sims}^{-1} \sum_{u=1}^{n_{sims}} \frac{\sum_{a=1}^{n_{age}} a\, N_{a,2002+n_{pro},u}}{\sum_{a=1}^{n_{age}} N_{a,2002+n_{pro},u}} + a_{\min} - 1$$

The Linear Programming Algorithm

LP is an active research branch of operation research that has proved to be useful in resource management. In this context an optimization problem is considered a linear one if all objective function and constraint coefficients can be arranged in a linear way. The linear optimization problem in this case, consists of finding the optimal catch allocation in order to maximize the overall catch or total revenue across all fisheries and subjected to a certain number of linear constraints. We used a revised Simplex algorithm (Press *et al.* 1992) to find the optimal vertex in this multidimensional space.

The objective function and constraint coefficients were computed primarily from the NOAA Fisheries Alaska Region blend dataset. It was averaged over the period 1997-2001, so all the coefficients represent averages from this time period. FMP-specific constraints were developed for both main areas (GOA/BSAI), namely TAC constraints for each FMP/AREA complex, special gear constraint for some species, lower and upper bound constraints on the variation of catch relative to average levels for each fishery, and constraints of the maximum allowable biological removals of each system.

Objective Function Coefficients

The target function consisted of coefficients derived from the blend data set for FMP managed species across different fisheries. The ex-vessel value ($V_{j,g}$) for each species and proportion retained by each fishery were used to compute the coefficients of the linear objective function:

$$A_g = \sum_{j=1}^{n_{species}} \sum_{k=1}^{n_{Areas}} V_{j,g} C^{bl}_{j,k,g} R_{j,g}$$

with the overall objective function to be maximized in year *i* is given as

$$\Theta_t = \sum_{g=1}^{n_{Fsh}} A_g Y_{t,g} \ ,$$

where

A_g Objective function coefficients applied to each fishery.

$C^{bl}_{j,k,g}$ Catch data from the BLEND dataset by species, sub-area and fishery.

$R_{j,g}$ Retained fraction of catch.

$Y_{t,g}$ Relative total catch between fisheries within each year (main result returned from the constrained optimization).

$V_{j,g}$ Estimated ex-vessel value of each species within different fisheries

t Year

j Species

k Sub-area

g Fishery

h Gear-type

Linear Constraints

In our optimization problem there are two types of constraints: values that are maxima or upper bounds and values that are minima or lower bounds. There were five types of upper-bound constraints and one type of lower bound constraint (presented below in consecutive order). The coefficients were computed only once for a specific FMP since the catch-composition data is constant (for this model version) over time and assumed known without error.

The bounding information (constraints) was based on a number of sources detailed below. Note that some constraints change over time (e.g., the ABC/TAC constraints).

Acceptable Biological Catch (ABC/TAC) Constraints

These constraints determined an upper bound equivalent to the TAC for each species in each sub-area. Each constraint has one coefficient and represents the average annual catch by FMP species and area as:

$$\sum_{g=1}^{n_{Fsh}} Y_g a_{j,k,g}^{ABC} \leq b_{j,k}^{ABC_t}$$

$$a_{j,k,g}^{ABC} = C_{j,k,g}^{bl}$$

where

$$b_{j,k}^{ABC_t} = TAC_{t,j,k}\ f_k$$

$TAC_{i,j,k}$ = Total allowable catch for species *j*, in sub-area *k* in year *i* and f_k is the split by area for a particular species and the bounds of the constraints are calculated as a function of a fixed allocation fraction of the TAC across sub-areas and the estimates TAC by year.

Gear type (G) Constraints

Gear allocations for a specific annual TAC were included to reflect the current practice. In the model, these constraints were specified as

$$\sum_{g=1}^{n_G} Y_{t,g} a_g^G \leq b^G$$

$$a_g^G = \sum_{g=1}^{n_{area}} C_{k,g}^{bl}$$

$$b^G = TAC_e f_k^G$$

e = index for species with gear restrictions

f_k^G is proportion of TAC allocated to each gear type (*G*) of each species in sub-area *k*.

For example, the sablefish TAC's are allocated between longline (fixed gear) and trawl gear. The model accounts for these allocations as added constraints.

Fishery Expansion Constraints

An upper limit constraints on relative catch are placed by FMP species (UL) so that relative catch does not grow unreasonably far beyond the baseline data (1997-2001 average).

$$Y_{t,g} a_g^{UL} \leq b_g^{UL}$$

b_g^{UL} is specified on input that typically ranged from 1.3 – 3. However, some alternatives specified different values (detailed below in the "Alternative descriptions" section).

Fishery Contraction Constraints

Based on extensive initial runs of this model, the optimal solution often eliminated a number of fisheries. To prevent this and to ensure that the catch remains positive, the following set of lower-limit constraints were applied.

$$Y_g a_g^{LL} \geq b_g^{LL}$$

$a_g^{LL_t}$ is a scalar for fishery g.

Overall Optimum Yield (OY) Constraint

The specification that the OY cap could not be exceeded was given as:

$$\sum_{g=1}^{N_{Fsh}} Y_{t,g} a_g^{OY} \leq b^{OY}$$

$$a_g^{OY} = \sum_{e=1}^{N_{sp}} \sum_{k=1}^{N_{Areas}} C_{e,k,g}^{bl}$$

$$b^{OY} = OY$$

OY = optimum yield summed for the geographical area (e.g., BSAI) for all target (FMP) species

e = index of target species used for optimum yield.

Note that this was generally 2 million metric tons (mt) for the BSAI and 800,000 mt for the GOA. However, some alternatives specified different values (detailed below in the "FMP descriptions" section).

Optimizing the Objective Function Subject to the Constraints

To find the optimum solution in standard tableau notation (Press *et al.* 1992) we can reduce the system of equations to the following array (with columns 2 to *g+1* corresponding to each fishery):

$$
\begin{array}{cccccc}
0 & A_1 & \cdots & A_i & \cdots & A_g \\
b_{i,j,k}^{ABC_1} & -a_{j,k,1}^{ABC_1} & \cdots & -a_{j,k,i}^{ABC_1} & \cdots & -a_{j,k,g}^{ABC_1} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b_{i,j,k}^{ABC_{m_{ABC}}} & -a_{j,k,1}^{ABC_{m_{ABC}}} & \cdots & -a_{j,k,i}^{ABC_{m_{ABC}}} & \cdots & -a_{j,k,g}^{ABC_{m_{ABC}}} \\
b^{MC_1} & -a_1^{MC_1} & \cdots & -a_i^{MC_1} & \cdots & -a_g^{MC_1} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
 & & & & & \\
b^{G_1} & -a_1^{G_1} & \cdots & -a_i^{G_1} & \cdots & -a_g^{G_1} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b^{G_{m_G}} & -a_1^{G_{m_G}} & \cdots & -a_i^{G_{m_G}} & \cdots & -a_g^{G_{m_G}} \\
b^{UL_1} & -a_1^{UL_1} & 0 & 0 & 0 & 0 \\
\vdots & 0 & 0 & -a_i^{UL_{n_i}} & 0 & 0 \\
b^{UL_{n_{UL}}} & 0 & 0 & 0 & 0 & -a_g^{UL_{n_{UL}}} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b^{OY} & -a_1^{OY} & \cdots & -a_i^{OY} & \cdots & -a_g^{OY} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b^{LL_1} & -a_1^{LL_1} & 0 & 0 & 0 & 0 \\
\vdots & 0 & 0 & -a_i^{LL_{n_{LL}}} & 0 & 0 \\
b^{LL_{n_{LL}}} & 0 & 0 & 0 & 0 & -a_g^{LL_{n_{LL}}}
\end{array}
$$

with

m_{ABC}	Number of ABC type of constraints (number of species that have TAC)
m_G	Number of gear type of constraints
m_{UL}	Number of upper limit constraints on relative catch of FMP species.
m_{LL}	Number of upper limit constraints on relative catch of FMP species.
m_{OY}	Number of overall yield constraints (only one).

Some of the coefficients (A_i , a_i^j) are zero but they are presented here in a general notation.

4.1.5.3 Data

Estimation of the 1997-2001 Catch by Species and Fisheries

We used the NOAA Fisheries Alaska Region blend estimates of catch by area, species, gear, and target species combined with observer fishticket (landing receipts recorded by Alaska Department of Fish and Game (ADF&G) statistical areas) data.

The North Pacific Groundfish Observer Program currently provides all of the information we have on fishery interactions with non-target species. Observers estimate total catch and species composition of the catch in a random sample of hauls. All animals are counted, weighed, and identified to the lowest practical taxonomic level, regardless of their status as a target species, or whether they will later be discarded by the vessel. The Observer Program is extensive, covering the majority of fishing effort in the BSAI and up to 30 percent of fishing effort in the GOA.

Despite the large size and extent of the Observer Program, not all fishing is observed at all times; only fishing vessels over 124 feet (ft) in length must carry an observer for all days fishing. Smaller vessels (60-124 ft) are only required to carry an observer for 30 percent of days fishing, and vessels under 60 ft are never required to carry an observer. Therefore, we had to extrapolate the data collected by observers to the reported catch from all (observed + unobserved) fishing in order to estimate the total catches of non-target species groups from all fishing for this analysis. This assumes that observed fishing and unobserved fishing have the same catch composition. Although this assumption is unverified, observer data is the best (and only) source of information on non-target species catch, so we use it.

Catches were estimated by species group for the recent domestic fishery, 1997-2001, using the following method: within each year, each vessels observed catch of a given species group was summed within statistical area, gear type, and week. A target fishery was then assigned to each vessels weekly catch, generally by assuming that the species with the highest retained catch for that week was the target species (the Programmatic SEIS describes target fishery designations and the specific algorithm for assigning targets). This is consistent with target assignments done as part of the inseason management system at the regional office. Catch by species (target and non-target, where available) was then summed for each year over all observed vessels within each area, gear, and target fishery. The ratio of observed non-target species group catch to observed target species catch within each area, gear, and target fishery was multiplied by the total reported (regional office blend-estimated) target species catch within that area, gear, and target fishery. Data from years prior to 1997 could not be assigned to target fisheries in a way which is consistent with total catch targets assigned by the Alaska Regional Office due to changes in the structure of the observer database. We do not consider this a problem because the most recent years of catch information are most valuable for the purposes of this analysis. Catches of other species, forage fish, and grenadiers were estimated for 1990 through 2001 as part of the annual stock assessment process and are reported in annual SAFE documents for the BSAI and the GOA.

The catch-composition data were processed to reflect area and time closures specific to each alternative. Since the catch-composition estimates were assigned to spatial/temporal strata, then the effect of changes in management measures could be reflected by modifying the catch-composition arrays accordingly. For example, if an alternative had specific closed areas, then the catch-composition data that fell within those categories were deleted. The notion here was simply to try to reflect how catch-composition might change under alternative area-time constraints.

Methods Used to Apportion the Estimates of Total Catch, Retained Catch, and Ex-vessel Value by Processor Group and Vessel Class and to Estimate Product Value by Processor Group

We used blend estimates of total catch and retained catch and fishticket estimates of retained catch for 1999-2001 to apportion the catch and ex-vessel value projections discussed above by processor group and vessel class. The resulting estimates of retained catch by processor group were used with 2001 estimates of product value per metric ton of retained catch to generate the estimates of product value. The methods used are discussed below.

Step 1: Define Processor Groups and Identify the Processors in Each Group

We defined the following six groups of inshore processors and six groups of at-sea processors to assist in analyzing the economic and social effects of the GOA and BSAI groundfish fisheries both historically and for the alternatives being considered in this Programmatic SEIS.

1. Large BSAI Pollock Processors (the American Fisheries Act [AFA] inshore sector processors that operate in or near Unalaska and Akutan)
2. Other Alaska Peninsula and Aleutian Island Processors
3. Floating processors (non-AFA floating processors)
4. Kodiak Processors
5. Southcentral Processors
6. Southeast Processors
7. Surmi Factory Trawlers
8. Fillet Factory Trawlers
9. Head and Gut Factory Trawlers
10. Longline Catcher Processors
11. Pot Catcher Processors
12. Motherships

We then identified the processors in each of these mutually exclusive groups.

Step 2: Distribute Catch and Ex-vessel Value Projections by Processor Group

We used blend estimates of total catch and retained catch by fishery, species (for the TAC species) and processor group from 1999-2001 to estimate the shares of total catch and retained catch by fishery and species associated with each processor group. The fisheries were defined by target species, gear and area. We then applied the total catch shares to the alternative-specific total catch projections to estimate alternative-specific total catch by fishery, species and processor group. The retained catch shares were used in a similar way with the alternative-specific retained catch and ex-vessel projections to generate comparable estimates of retained catch and ex-vessel value. Data for 1999-2001 were used because the AFA was implemented in 1999 and it significantly changed the shares of catch among processor groups.

Step 3: Estimate Product Value by Processor Group

For each inshore processor group, we used 2001 Alaska Commercial Operators Annual Report (COAR) estimates of groundfish purchases and product value by species to estimate product value per metric ton of retained catch. For each at-sea processor group, we used 2001 COAR product price data for at-sea processors, supplemented by 2001 product price data provided by representatives of the Head and Gut Factory Trawlers, together with Weekly Production Report production and retained catch data to estimate product value per metric ton of retained catch.

Step 4: Define Catcher Vessel Classes and Identify the Catcher Vessels in Each Group

We defined the following nine classes of groundfish catcher vessels to assist in analyzing the economic and social effects of the GOA and BSAI groundfish fisheries both historically and for the alternatives being considered in this Programmatic SEIS.

1. Bering Sea pollock trawl catcher vessels greater than or equal to 125 ft in length
2. Bering Sea pollock trawl catcher vessels 60 to 124 ft in length
3. Diversified AFA-eligible trawl catcher vessels greater than or equal to 60 ft in length
4. Non-AFA trawl catcher vessels greater than or equal to 60 ft in length
5. Trawl catcher vessels less than 60 ft in length
6. Pot catcher vessels less than or equal to 60 ft in length
7. Longline catcher vessels less than or equal to 60 ft in length
8. Fixed gear catcher vessels 33 to 59 ft in length
9. Fixed gear catcher vessels less than or equal to 32 ft in length

We then identified the catcher vessels in each of these mutually exclusive vessel classes.

Step 5: Estimate Retained Catch and Ex-vessel Value by Catcher Vessel Class

We used State of Alaska fish ticket estimates of retained catch by species, area, processor group and vessel class from 1999-2001 to estimate the share of retained catch by species and area associated with each catcher vessel class. We then applied the retained catch shares to the alternative-specific retained catch and ex-vessel value projections by processor group to generate alternative-specific estimates of retained catch and ex-vessel value by species, area and catcher vessel class.

Assumptions

The resulting estimates of total catch, retained catch, ex-vessel value, and product value are based on the assumptions that none of the following will vary either by alternative or from what has been observed recently for the BSAI and GOA groundfish fisheries:

- species composition (i.e., bycatch rates) of TAC species in any individual fishery, where a fishery is defined by area, gear and target species;
- distribution of catch among processor groups in any individual fishery;
- retention rates for a fishery, species and processor group;
- product mix for a species and processor group;
- distribution of retained catch among catcher vessel classes for each processor group;
- ex-vessel prices; and
- product prices.

We do not believe these assumptions are either equally valid for all the alternatives or valid for most of the alternatives. Unfortunately, the information necessary to estimate alternative-specific differences in bycatch rates, the distribution of catch among processor groups and vessel classes, retention rates, product mix, ex-vessel prices, or product prices is not available. This problem is addressed qualitatively in the sections that present the projections of ex-vessel value and product value for the various alternatives.

Estimates of Ex-Vessel Value Per Metric Ton of Retained Catch

We used 2001 Alaska COAR groundfish purchase data to estimate ex-vessel value per metric ton of catch by species, gear and area for the species that are not almost exclusively processed at sea. For the other species, such as BSAI Atka mackerel, flatfish and rockfish, we estimated that the ex-vessel value per metric ton of retained catch was 40 percent of the product value per metric ton of retained catch.

Description of the Fishery Definitions Used in the Model

In the GOA 32 different fisheries were defined as having gear-area-target significance. These are listed in Table 4.1-14. Table 4.1-15 lists the 35 fisheries defined for the eastern BSAI regions (Figures 4.1-2 and 4.1-3).

To summarize characteristics of each fishery we devised a method to show the diversity of species mix observed in the catch. We used Simpson's (1949) index of diversity (κ) commonly used in population biology. For each fishery the index is computed as:

$$\kappa = \frac{1}{\sum_{i=1}^{nspp} p_i^2}$$

where p_i is the proportion of catch (in biomass) over all species or species groups (55 different categories in the GOA and 56 in the BSAI). This index can be interpreted as (roughly) the "effective number of species." For example, Figure 4.1-4 illustrates a hypothetical catch composition of 5 species caught in 4 different fisheries at different proportions. The effective number of species for "Fishery A" is very close to 1.0 (1.02) due to the fact that 99 percent of the catch is attributed to "Spp_1." At the other extreme, "Fishery D" caught all 5 species in equal proportions leading to an index value exactly equal to 5. In "Fishery B" only two species are caught in equal proportion, hence the effective number of species is exactly 2. In "Fishery C" all five species occur but in diminishing proportions and hence the effective species is slightly lower than 3.

Presenting the species mix for fisheries in this way provides a simple summary way of examining the differences between fisheries. More importantly, it can be used to show the effect of how sampling variability and time trends may affect the estimated catch composition of each fishery. For example, computing the effective number of species using the 5-years of NOAA Fisheries blend data in aggregate (average catch by species and fisheries) showed that for both the GOA and BSAI regions, flatfish and rockfish fisheries tend to have higher catch diversity (since these are fundamentally mixed-species fisheries) while pollock fisheries and fisheries using pot gear tended to have the lowest diversity (Figures 4.1-5 and 4.1-6). However, these figures also show that the catch diversity in some fisheries can be quite different between years. Presumably this is largely due to sampling error and partly due to real changes in catch composition. Another contribution to this variability could be how target fisheries are defined. i.e., a target fishery is defined based on the dominant species catch reported by week. If a vessel in fact targets multiple species within a week, then the diversity of the reported catch may be unrealistically high. These factors highlight important caveats regarding the ability to accurately predict how catch diversity levels may change from one year to the next. These problems would be exacerbated by using subsets of catch composition data within years due to closed areas. For this reason, we chose to assume that the best available estimates of fisheries catch composition were based on data aggregated from 1997-2001. Since many of these fisheries defined may reflect relatively small levels of catch, we evaluated this index for the major fisheries and examined the trend over time. For the GOA, 11 of the 32 fisheries represented 80 percent of the catch. These fisheries still had considerable inter-annual variability in catch diversity (Figure 4.1-7) but no apparent trend. In the BSAI, 8 fisheries represented 91 percent of the catch and had less inter-annual variability (Figure 4.1-8). The flatfish-fisheries appeared to have a slightly increasing trend in diversity from 1997-2001. This suggests that the assumption of constant species compositions may be inappropriate. Further research on what has caused this apparent trend in catch diversity is warranted.

4.1.5.4 Critique of Assumptions and Approach

Forecasting fisheries behavior is an endeavor fraught with uncertainty. Even under a relatively constant management system, changes in socio-economic and environmental conditions can result in substantial future uncertainty. Add in a complex set of alternative management measures, such as those presented in this document, and the uncertainty is magnified. The following describes an attempt to model key aspects of the current fisheries management system and, to the extent possible, modifications according the specific management measures for the four Alternatives (and their ranges). The model's predictive power given the system complexity is poor. However, this multi-species technical interaction model does provide a more objective approach to evaluate alternative management actions compared to single species examinations.

The NPFMC Scientific and Statistical Committee (SSC) provided feedback on the modeling approach. In particular, they raised a number of concerns about using this type of approach (i.e., using LP to mimic fisheries management). For example, using ex-vessel value estimates as part of the objective function fails to reflect the costs. Unfortunately, extensive cost data are unavailable. The SSC also noted that ex-vessel prices are likely to change over time. While modeling how these may change over time would be valuable, the degree of difficulty and added complexity prohibited development along these lines. This aspect seems unlikely to have a large scale effect over the five-year simulation projection.

Within alternatives, the catch-composition array is assumed to be constant. That is, there is no random variability nor are there trends in the underlying catch composition (within a fishery). In reality, catch-composition values are likely to vary from year to year. Observation error and other sources of variability (and potential biases) mask this variability. The model was developed so that catch-composition variability can be implemented in the simulation. However, since available data are limited (five years) the magnitude of this uncertainty could not be assessed in time for this analysis. Explicitly modeling the catch composition of each fishery is an area of research that needs to be pursued, particularly as dynamic species interactions are introduced.

The fact that the catch-composition array is constant over time may not be unreasonable given the short time frame of the main projections (2003-2007). However, the long-term projections (to 2023) results that were also provided should be viewed much more cautiously. These long-term projections were done to provide some indication of general trends between stocks. For the 5-year time frame used for estimating the catch composition by fisheries and species matrix (1997-2001), there appeared to be little or no trend in the diversity of the catch for the main fisheries (e.g., Figure 4.1-8). The annual variability in the diversity of the catch highlights the importance of including details on the effect of area closures on catch by species and fisheries matrices. Clearly, sampling error plays a large role and as finer geographic resolution is included, the effect of sampling error will increase. This will likely compromise real changes in bycatch patterns due to area closures.

The uncertainty in current abundance levels is not modeled. The point estimates for parameter values (e.g., the numbers-at-age) in the assessments published in the 2002 SAFE are used. This clearly underestimates the variability in the current abundance levels for all species of groundfish. Under FMP 3.2 estimation uncertainty is accounted for and is applied as a risk averse adjustment. It is possible to add this type of estimation uncertainty explicitly within the projection model. However, time limitations and the additional complexity in the presentation of the results would detract from the analysis.

The SSC also recommended that alternative objective functions be considered. They noted that the purpose of the model is to project likely management actions under the alternatives, and hence, it might be useful to express the objective as a minimization of the weighted sum-of-squared deviations between actual and target levels of catch where the weights reflect management preferences for meeting TACs. This would provide a non-linear objective function (specifically, quadratic) with linear constraints and would add a seemingly desirable feature to the model, at least for the status quo (FMP 1) specification. Time limitations precluded implementation of a Quadratic Programming approach. Furthermore, this approach would require subjective specification of the "weights" for the different alternatives. For the Linear Programming approach used here, the (imperfect) objective function requires fewer assumptions about how weights may change by alternative.

For this implementation, the results were largely insensitive to the objective function specification. Some of assumptions that constrained the solution space most severely were limits placed on the ability of individual fisheries to expand and contract relative to the patterns observed during 1997-2001. Sensitivity analysis showed that as these bounds were relaxed, the overall catch and revenue (based on ex-vessel value) increase at the expense of greater departures from the status quo (and increased sensitivity to the objective function). For these sets of model specifications, bounds were selected based on discussions with economists in the iterative process of examining model results. There is clearly room for improvement in specifying these sets of constraints. One approach would be to poll a wider group of experts in arriving at more refined sets of limits. Such a setting would also provide needed feedback for model improvements and may provide insights to management on the relative benefits of different fisheries.

In summary, the complex interactions among changes in biomass levels, fisheries economic performance, and management effectiveness are just some of the reasons why any such forecast must be viewed cautiously.

4.1.5.5 Description of the Alternatives

The projection model was designed to approximate the general patterns of catch that might be expected given the multispecies nature of groundfish fisheries. The analyses rely on two main sources of information: 1) observer and fish-ticket data (the blend data); and 2) stock assessment estimates of population parameters, abundance-at-age in 2002, and recruitment variability. The first step in developing model configurations for each of the example FMPs was to process the observer catch-composition data to reflect, to the extent possible, the impact of each FMP. The baseline catch-composition data was derived from observer and fishticket reports for the period 1997-2001. For certain fisheries where characteristics changed dramatically (such as the implementation of the AFA in 2000) the number of years included differed from this baseline. The details of estimating the catch-by-fisheries data used in the model is presented in a separate section below.

The second part of setting up alternative specifications involved limiting TACs either through different harvest control rules or specific ABC reductions. The following sections provide some descriptions about how the model is affected by the different alternatives.

For the main reported species, the PSC species, and the other non-target species have been compiled for gear-area-target fisheries using 1997-2001 as the baseline average (except that for all FMPs but FMP 2.2, the EBS pollock fishery and the Aleutian Islands Atka mackerel fisheries the average of 2000 and 2001 was used to better reflect the AFA and other recent management measures). Unless otherwise noted, the values for retention rates are shown in Tables 4.1-16 and 4.1-17 while the estimated average ex-vessel price by species and gear type is given in Tables 4.1-18 and 4.1-19. The catch by species and fisheries for the GOA and BSAI is available from the web (www.fakr.noaa.gov/sustainablefisheries/seis/data). An overview of the key differences between the alternatives as modeled is given in Table 4.1-20. It is important to note that yield and biomass results for any alternative cannot typically be attributed to any single aspect of alternative specification since all aspects are being implemented simultaneously.

FMP 1

This alternative is considered as the baseline status quo relative to the 2001 fishing year. The ABC follows Amendment 56 for setting quotas. Furthermore, as appropriate the ABC setting for FMP 1 is adjusted downward as appropriate and typical based on recommendations from assessment authors and NPFMC. For example, in the 2002 SAFE the ABC fishing mortality for a number of species was set at $F_{t,u}^{Alt1} = \omega F_{t,u}^{ABC}$ where ω is 0.87 for Pacific cod (in both the BSAI and GOA; see step 9) above for the definition of $F_{t,u}^{ABC}$). For pollock ω is an added buffer (as a function of spawning biomass) as presented in the GOA pollock SAFE by Dorn et al. (2002). For non Steller sea lion forage species (α =0.05) while for pollock, Pacific cod, and Atka mackerel, α =0.5 (see step 9) above for the definition of $F_{t,u}^{ABC}$). In the BSAI, an overall OY cap of 2 million mt of groundfish catch was an added constraint while for the GOA the cap was set at 800,000 mt (FMP species only).

FMP 2.1

For this alternative the catch-composition data is the same as FMP 1 with one exception. The pre-IFQ catch-composition rates for sablefish fisheries and earlier estimates of halibut mortality were used. This represented only a small difference and is available on the website (www.fakr.noaa.gov/sustainablefisheries/seis/data). The F_{ABC} for this FMP is set to F_{OFL} (the overfishing level which by NPFMC definitions equals the point estimate of F_{msy}). This fishing mortality rate is held constant over all stock sizes, including as the stock drops below $B_{40\ percent}$ (i.e., $F_{t,u}^{ABC} = F_{msy}$ for $B_{t,u} > 0$). For all age-structured stocks the F_{msy} was set equal to the SPR fishing mortality rate of $F_{35\ percent}$. For survey biomass stocks (Tier 4 and lower from Amendment 56) the ABC was set the overfishing level (OFL). Additional measures for Steller sea lion prey species were omitted.

In FMP 2.1, the OY is set to the sum of ABC's in both the GOA and BSAI. Also, there are no constraints due to PSC limits. For example, bycatch of Pacific halibut will not constrain fishery development. The fishery-expansion constraint is set to 100 (i.e., fisheries can expand effort beyond the average level observed over 1997-2001).

FMP 2.2

Example FMP 2.2 is characterized as being similar to FMP 1 except that the OY is set to the sum of ABC's in both the GOA and BSAI instead of a fixed cap. Also, the maximum permissible ABC value was used instead of the author's adjustment (see ω above).

FMP 3.1

This FMP is very similar to FMP 1 except that the constraint on Pacific halibut mortality is reduced by 10 percent (more constraining). Also the "author's recommendation" for ABC's (see ω above) are omitted (e.g., the GOA pollock OFL buffer).

FMP 3.2

For example FMP 3.2 the catch of species by fisheries data are modified to reflect improved rationalization. That is, the bycatch of discarded species is reduced by using existing total catch estimates and changing the fraction that is discarded. Specifically, for given species and fishery, the catch that has been estimated as being discarded in the data will be reduced by 20 percent. This means that under fisheries rationalization, the fishing behavior will change such that the actual incidental catch will be reduced. This change is implemented by modifying the input data on catch of species by fisheries (sometimes referred to as the bycatch matrix). These data are available on the website: http://www.fakr.noaa.gov/sustainablefisheries/seis/data.

Another aspect of improve rationalization specifies that the retention rates of what is caught in the future will increase i.e., the rate of discarding species that are caught will be reduced 20 percent. This change is implemented by modifying the retention rate matrices (for GOA and BSAI shown in Tables 4.1-21 and 4.1-22).

For example FMP 3.2, the OY is to be set to the sum of ABC's instead of the current 2 million mt capacity. Also, the halibut mortality limit is reduced by 30 percent relative to FMP 1.

One objective under FMP 3.2 was to incorporate formal estimates of uncertainty already estimated in many of the stock assessments. A large-scale research effort on developing methods to use fully Bayesian risk-averse methods continues and a version of this development is used here.

Under the current system a common assumption is that the $F_{35\ percent}$ rate is a good proxy for F_{msy} (and thereby determines of the F_{OFL}). Similarly, $B_{35\ percent}$ is commonly taken as a good proxy for B_{msy}. Given the parameter values from stock assessment results to determine these quantities, the NPFMC as implicitly accepted that the $F_{40\ percent}$ fishing mortality rate is suitably risk averse *regardless of uncertainty in future recruitment and current stock size.* The risk-averse adjustment to the F_{msy} (here assumed to be $F_{35\ percent}$) formally accounts for the uncertainty in current stock size and future recruitment. The method developed requires (in addition to the standard selectivity, average mass-at-age, natural mortality, current numbers-at-age, and maturity-at-age schedules) estimates of the covariance matrix of the current numbers-at-age and the time series of recruitment estimates. The advantages of the method developed include: 1) that the upper bound of the F_{ABC} is set to a constant level of risk-aversion; 2) simulations (to determine the appropriate adjustment level) can be avoided; 3) analytical solutions are available for all steps (except one final maximization); and 4) the ability to assess the value of improving estimates (reducing variance) of current stock size. A key feature of this analysis is the development of a method for calculating the stock-recruitment relationship given estimates of B_{msy} and F_{msy} and the other age-specific schedules listed above. The actual values for the adjustment are shown in Table 4.1-23 and a presentation of two scenarios where the risk-averse adjustment appears to be due to different sources is shown in Figure 4.1-9.

The application of the risk averse adjustment was applied for all stocks:

$$F_{Har} = F_{msy} * \text{Adjustment}$$
$$F_{ABC} = \min(F_{Har}, F_{40\ percent}, F_{OFL\_Alt1})$$

While for rockfish species an added measure of precaution was applied where:

$$F_{ABC\_RF} = \min(F_{60\ percent}, F_{Har})$$

FMP 4.1

In this example FMP, the OY constraint is set to sum of ABC's. Note that this is effectively the same as omitting an OY constraint since the individual species ABC's are constraints themselves. The species catch by fisheries was modified so that fisheries with more than 33 percent bycatch (a species not listed as the target) were eliminated. Pacific cod, pollock and arrowtooth flounder were not included as a bycatch species to these fisheries.

Uncertainty corrections to the ABC's were based on survey CVs. Also, the F_{ABC} was set to $F_{75\ percent}$ for all Steller sea lion prey species and for all species of rockfish. Note that uncertainty corrections applied to the $F_{75\ percent}$ values too.

Agency analysts discussed how to incorporate the formal estimates of uncertainty already estimated in some of the stock assessments (e.g., AD Model Builder applications or Bayesian analyses). This is an ongoing area of research; however, the example regime was deliberately designed to be applicable to all stock assessments regardless of the software used. Incorporating formal estimates of uncertainty available for some stocks would continue to impose the largest adjustments only on the best known stocks. For example, the current process for TAC setting does not reduce harvest levels when the reference biomass level ($B_{40\ percent}$) cannot be estimated for stocks in Tiers 4 to 6 of Amendment 56/56 ABC and OFL definitions. Stocks qualify for management under Tiers 4 to 6 only if reference stock levels cannot be estimated reliably.

The formal incorporation of uncertainty was accomplished by setting the fishing mortality rate associated with ABC (F_{ABC}) at specified fractions of the maximum allowable fishing mortality rate (maximum F_{ABC}), where this fraction varies directly with the uncertainty (variance) of the survey biomass estimates. Specifically, this is accomplished by computing the average coefficient of variation for the survey biomass estimates in the time series and then computing the lower bound of the 90 percent confidence interval for a lognormal distribution with this coefficient of variation and a median of unity. This lower bound is the specified fraction by which to reduce maximum F_{ABC}. The specified fraction by which to reduce maximum F_{ABC} is provided as input to the model for FMP 4.1. All target species with biomass estimates were analyzed. Exceptions are made in the model projections for some species whose stock assessment F_{ABC} are below maximum F_{ABC}. These adjustment values (corresponding to the lower bound of the 90 percent confidence interval) are given in Table 4.1-24.

For FMP 4.1 the prohibited species cap for Pacific halibut mortality was reduced to 50 percent of the current level (causing a greater level of constraint).

FMP 4.2

No fishing was allowed for the 5 year-projection. We presume that under this example FMP, fisheries authorized following review, would take the form of that regime being illustrated by FMP 4.1.

4.1.5.6 How Model Results Were Applied in Assessing Impacts of the Alternatives on Different Resources

Target, Forage, Prohibited and Non-Specified Species

For the target species, the multi-species, multi-fisheries simulation projection model provided fundamental dynamics to the model behavior. That is, as the biomass of an FMP species changed in the future, the constraint (via ABC/TAC control) also changed. The outputs from the model were primarily intended to reflect these dynamics and the interactions with the species composition of the different fisheries.

The significance of the impacts on target species were evaluated with respect to five effects: 1) fishing mortality, 2) change in biomass level, 3) spatial/temporal concentration of the catch, 4) prey availability, and 5) habitat suitability.

The significance of the effects of the alternative fishing mortality levels are evaluated with respect to the overfishing mortality rates as set forth in Amendments 56/56. Fishing mortality rates that exceed the overfishing mortality rate are considered to jeopardize the capacity of the stock to produce MSY on a continuing basis and adversely impact the sustainability of the stock. A related measure of this potential is indicated by change in biomass levels. The significance of effects of the current spatial/temporal concentration of the catch, and the level of prey availability and habitat suitability for target species are evaluated with respect to each stock's current size relative to its MSST. An action that jeopardizes the stock's ability to sustain itself at or above its MSST is considered to adversely affect the sustainability of the stock.

Species or species complexes that fall within Tiers 1 though 5 have estimates of the current fishing mortality rates are evaluated with respect to exceeding the overfishing mortality rate (fishing mortality effect). Species or species complexes that fall within Tiers 1, 2, or 3 have reliable estimates of MSST and are evaluated for the effects of spatial/temporal concentration of the catch, prey availability, and habitat suitability. Species or species complexes that fall within Tiers 4, 5, or 6 do not have reliable estimates of MSST and therefore we cannot evaluate the significance of these effects. This inability to evaluate the significance of the effects also occurs for the forage, prohibited and non-specified species. Since several species or species complexes do not have estimates of abundances-at-age, in this version of the model, their abundance levels simply reflect the most recent estimate. For these groups, analysis of the effects of the example FMPs were limited to catch projections and likely consequences given patterns in related fauna.

Habitat

A quantitative estimate of habitat impact under each example FMP required an estimate of the fishing effort applied in areas remaining open under each scenario. The amount of effort should take into account the catch levels expected under the alternatives in each TAC management area (and the amount of catch taken under the baseline that would have been taken inside and outside the area to being closed by the FMPs). Because of the limitations in the multispecies bycatch model, not all species and their area specific catches could be easily explained by the stock dynamics. The impact of alternative-specific management practices on model outputs were also difficult to interpret on detailed area-fishery and species scales. While stockwide projections of most major species were more easily understood, catch by TAC management area was required for the effort estimation. The time required to complete a rigorous analysis to validate (and in some cases correct) area-specific catch levels exceeds the time available to prepare this Programmatic SEIS. This necessitated a more qualitative evaluation in this Programmatic SEIS of the expected impacts on habitat based on known fishery characteristics.

Seabirds

The analysis of direct and indirect effects on seabirds relied on the projection model's estimates of fishing effort (in mt) by different gear types in the BSAI and GOA under the different FMP bookends. Hook-and-line (longline) and trawl effort were particularly important for analysis of incidental take. For analysis of FMP 2.1, the projection model's output essentially eliminated the BSAI longline cod fishery and tripled the GOA longline cod fishery, based on small price differentials between gear types. This situation was considered an unrealistic artifact of the model's rules for allocating catch between gear types in lieu of specified allocations. For FMP 2.1, the BSAI longliners were assumed to take about the same volume of cod as they have under the baseline conditions, with the balance going to trawl and pot gear. For the GOA, longliners were assumed to take the same percentage of the cod TAC as they had under the baseline which translated into a moderately higher catch because of the higher TAC. The implications of different spatial/temporal restrictions were also analyzed, especially as they related to effects on prey availability for nearby seabird colonies and potential for trawling in eider critical habitat areas. Other factors that were not modeled, including implementation of seabird protection measures and the potential for a directed forage fish fishery, were also included in the analysis.

Marine Mammals

Results from the multi-species management model were used to analyze the effects of the example FMPs on marine mammal populations. Catch projections from the model were used to estimate incidental take of marine mammals and evaluate harvest levels of marine mammal prey species. Total projected groundfish catch was averaged from 2003-2007 for each example FMP. This average projected catch was multiplied by the incidental take rate (marine mammal takes/mt of groundfish) of each marine mammal species derived from Angliss *et al.* (2001) to estimate changes in incidental take under each example

FMP. The average annual fishing mortality rate (*F*) projected from 2003-2007 was compared to the baseline (2002) to determine the change in *F* expected under each alternative bookend for all key marine mammal prey species. Percent changes in *F* relative to the baseline were used to indicate changes in the prey field for affected marine mammal species. These analyses employed the model results as they were reported, without modification, and therefore incorporated all the assumptions that went into the model.

Socioeconomic

The output from the multi-species management model were used as the starting point for development of the socioeconomic impact model referred to in the remainder of the document as the Sector Model. The Sector Model uses the multi-species management model output of catch of each species by gear in each area and distributes those catches and associated values as well as income and employment to the various fishing and processing sectors that depend on the groundfish resources and to the geographic regions where the activities occur and where factor owners reside. A detailed description of the Sector Model is included in Section 4.1.7.

Ecosystem

The multi-species bycatch model was used to derive indicators for assessing the impacts of the alternatives on the ecosystem. The indicators chosen were ones that would characterize changes in predator/prey relationships, energy flow, and diversity. In predator/prey relationships, model outputs were used to obtain estimates of pelagic forage biomass of target species (walleye pollock and Atka mackerel in the BSAI and walleye pollock in the GOA). Total biomass of these species was used to derive this index. Bycatch estimates of squid, herring, and the managed forage species group from the model were used as another indicator of the magnitude of fishing impacts on these other forage species. Trophic level of the catch was an indicator of fishing down the food web, which is the sequential fishing down of species high in the food chain such that over time the fisheries are left only with mid-trophic level species as targets. Model estimates of catch biomass for each target and nontarget species group were combined with estimates of trophic level of each species group derived from food habits information to obtain estimates of the overall trophic level of the catch for each example FMP. Fishing effects on top predator species were evaluated through model estimates of bycatch of sharks and birds. Model estimates of total retained catch and discards for target and nontarget species were used as an indicator of the effects of the alternatives on energy cycling characteristics of the ecosystem through energy removal (total retained catch) or energy redirection (discards). Finally, model estimates of bycatch of HAPC biota were used as an indicator of effects of fishing on functional (structural habitat) diversity.

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Glossary of symbols used in description of the model

Dimensions

a_{max}	Maximum age used in the model (plus group)
a_{min}	Minimum age used in the model
n_{age}	Number of ages in the model
n_{gear}	Number of gear types for which separate selectivity schedules are used (as in the assessments)
n_{pro}	Number of years to project beyond the initial year in each simulation
n_{sims}	Number of simulations
n_G	Number of gears with allocation constraints
n_{Fsh}	Number of fisheries
n_{sp}	Number of species
n_{area}	Number of management areas defined for each species

Indices

a	Relative age index, $1 \le a \le n_{age}$
g	Fishery index, $1 \le g \le n_{Fsh}$
k	Sub-area
h	Fishing gear type
t	Projection year index, $1 \le t \le n_{pro}$
u	Simulation index, $1 \le u \le n_{sims}$
i	Alternative index
j	Species index

Life History and Fishery Parameters

d_h	Proportion of total instantaneous fishing mortality rate distributed to gear *h*
M_a	Natural mortality rate at age *a*
m_a	Proportion of age *a* fish that are mature
w_a	Weight-at-age in the population
p	Proportion of females in the population
$s_{a,h}$	Selectivity of gear type *h* for fish of age *a* (scaled so that max(*s*)=1)
$w_{a,h}$	Weight of age *a* fish as sampled by gear *h*

Other Parameters and Expressions Used in Projections

SPR	Spawning biomass per recruit
ABC	Acceptable biological catch
TAC	Total allowable catch
OY	Optimum yield summed for the geographical area (e.g., BSAI) for all target (FMP) species
B_{ref}	A parameter of the control rules used to set the overfishing rate and to constrain F_{ABC}
$B_{t,u}$	Spawning biomass in projection year *t* of simulation *u*
C_{2002}	Actual catch observed in 2002 (or projected to be caught)
$C_{t,u}$	Catch in projection year *t* of simulation *u* for each population after the LP
$F_{t,u}$	Fishing mortality rate in projection year *t* of simulation *u* for each population
F_{lim}	A parameter of the control rule used to set the overfishing rate
F_{ref}	A parameter of the control rule used to constrain F_{ABC}
$X_{t,u}$	Fishing mortality rate in projection year *t* of simulation *u* for each population after the LP
$\phi_{a,t,u}$	Total mortality rate between the beginning of the year and the spawning period
$N_{a,t}$	Numbers at age *a* in projection year *t*
$N_{a,t,u}$	Numbers at age *a* in projection year *t* of simulation *u*

n_a Numbers at age a in 2002
$O_{t,u}$ Rate of fishing mortality that constitutes overfishing in projection year t of simulation u
P Probability of overfishing in at least one year of the projection period
R_{2003} Recruitment for 2003 predicted in the 2002 stock assessment
$R_{t,u}$ Recruitment in projection year t of simulation u
$T_{t,u}$ Total biomass (between ages a_{min} and a_{max}) in projection year t of simulation u
TAC_{2002} TAC actually specified for 2002
$X_{t,u}$ Fishing mortality rate that sets catch in projection year t of simulation u equal to C_{max}
A Average age for each stock in the final projection year across all simulations
f_k Proportion of the catch allocated to sub-area k for a particular species

Parameters and Expressions Used in the LP

Θ_t Total objective function value
m_{ABC} Number of ABC type of constraints (number of species that have TAC)
m_G Number of gear type of constraints
m_{UL} Number of upper limit constraints on relative catch of FMP species
m_{LL} Number of upper limit constraints on relative catch of FMP species
m_{OY} Number of overall yield constraints (only one)
A_g Objective function coefficients applied to each fishery
$C_{j,k,g}^{bl}$ Catch data from the BLEND dataset by species, sub-area and fishery
$R_{j,g}$ Retained fraction of catch
$Y_{t,g}$ Relative total catch between fisheries within each year (main result returned from the constrained optimization)
$V_{j,g}$ Estimated ex-vessel value of each species within different fisheries

Computation of SPR values

Using species specific demographic values (see www.fakr.noaa.gov/sustainablefisheries/seis/data), fishing mortality rates (e.g., $F_{40\%}^{p}$) that would reduce the female spawning stock (per recruit) to some fraction of the unfished level. The age-specific factors are: selectivity, natural mortality, maturity, and weight or fecundity. For example, to compute $F_{40\%}^{p}$ an algorithm to solve the following set of implicit equations was used:

$$0.4B_{100\%}^{p} = \sum_{a=1}^{n_{ages}^{p}-1}\left[w_a^p\, m_a^p \prod_{j=2}^{a} e^{-\left(M_{j-1}^{p}+F_{40}^{p}s_{j-1}^{p}\right)}\right] + w_{n_{ages}^p}^{p}\, m_{n_{ages}^p}^{p} \prod_{j=2}^{n_{ages}^{p}} e^{-\left(M_{j-1}^{p}+F_{40}^{p}s_{j-1}^{p}\right)}\left(1-e^{-M_{n_{ages}^p}^{p}-F_{40}^{p}s_{n_{ages}^p}^{p}}\right)^{-1}$$

where $B_{100\%}^{p}$ corresponds to the spawning stock per recruit of population p in an unfished equilibrium state. This information was used within the management rule that determines the quota. For some species and alternatives different F-spr rates were used.

4.1.6 Habitat Impacts Model

To evaluate the impacts of fishing on living habitat the model developed by Fujioka (2002) is used. This model incorporates the basic factors determining impacts of fishing on habitat. Given values, either estimated or assumed, of 1) fishing intensity, f (= absolute effort in area swept per year ÷ area size), 2) sensitivity of habitat to fishing effort, q_H, and 3) habitat recovery rate, ρ, the model predicts a value of equilibrium (i.e., long term) habitat level, H_{eq}, as a proportion of the unfished level, H_0.

$$H_{eq} = H_0 \cdot \rho S/(I + \rho S) \qquad \text{Where } H_0 = \text{unfished habitat level, } I = f\,q_H \text{, and } S = e^{-I}.$$

Habitat impact or effect level, E, for the given effort, sensitivity, and recovery rates, would be $1 - H_{eq}$. Letting $H_0 = 1.0$, then

$$E = I/(I + \rho S)$$

Various habitat features could be impacted by fishing gear. Initially, this analysis focused on the impact to the biostructure habitat feature where biostructure is living habitat provided by organisms such as soft corals, tunicates, and sponges with assumed recovery rates of 2 to 15 years. Where applicable we also attempted to address impacts to longer lived living habitat with slower recovery rates (i.e., 200 years) such as gorgonian corals (e.g., red tree coral, Primnoa). A widely accepted management policy has been to avoid impacting such long lived organisms.

Habitat Sensitivity Rate (q_H)

The habitat sensitivity rate, q_h, is the proportion of habitat in the path of the net impacted by one pass of the net. The organisms considered here as indicators of habitat sensitivity range from relatively small and flexible (such as soft corals) to larger, more erect organisms (such as sea whips). Vulnerability of the organisms varies greatly depending on their physical characteristics and the characteristics of the trawl gear. The vulnerability may be difficult to determine. Certain features of the gear may make the gear more damaging to one type of organism than to another type. For biostructure sensitivity to bottom trawl gear two values of q_H, 0.10 (less sensitive) and 0.25 (more sensitive) are proposed as plausible.

Habitat Recovery Rate (ρ)

Recovery rate, ρ, reflects the rate of change of impacted habitat back to unimpacted habitat, H. In the absence of further impacts, impacted habitat would decrease exponentially till all habitat was in H, the unimpacted condition. The recovery time, R, can be thought of as the average amount of time the impacted habitat stays in the impacted state, which would equal $1/\rho$ (in the absence of further impacts).

Little is known about the recovery rate of various benthic organisms that provide biostructure in waters off Alaska. The recovery rate as modeled includes any recruitment required to initiate recovery and the growth necessary to reach a size that is necessary to provide habitat function. Recovery times as much as 15 ($=1/\rho$) years are within a plausible range. For this analysis two values of biostructure recovery rates are utilized to cover a plausible range of impact, Scenario 1 where ρ=.5 (2 yr or rapid recovery), and Scenario 2 where ρ=.0667 (15 yr or long recovery). Table 4.1-25 shows the corresponding impact levels for given levels of fishing intensity. For example, for an f = 0.25 (bottom area swept once every four years), habitat with a recovery rate of ρ=0.50 (recovers in two years) and a sensitivity rate q_H = 0.10 (one-tenth of organisms removed per sweep of the net) the long term impact level, E, would be 0.049. That is, the habitat would be reduced slightly to H_{eq} = 95.1 percent of its unfished level. If recovery rate ρ was 0.067 (takes 15 years to recover) and sensitivity q_H =0.25 (one-fourth of organisms removed per sweep of the net) the impact level would be 0.499, or down to H_{eq}=50.1 percent of its unfished level. It can be seen that as f increases, impact level increases, or the equilibrium level of habitat decreases.

Fishing Effort or Intensity (*f*)

Bottom trawl fishing effort has been estimated for each 5x5 km block in the Bering Sea, Aleutian Islands, and the GOA regions by Rose and Jorgenson (2002). Fishing intensity of a block is the fishing effort per year measured in area swept a proportion of area of the block.

Habitat Impact (*E*)

Impact is a function of sensitivity, recovery rate, and fishing intensity. For the given values of sensitivity q_h, and recovery rate ρ, discussed above, and bottom trawl fishing intensity *f* estimated for each 5x5 km block, habitat impact, $E_i = I_i/(I_i+\rho S_i)$, can be calculated for the 5x5 km block represented by the *I* parameter. Larger values of *E* equate with more impacts. Results for a region can be presented in a single value as a mean impact, frequency distribution of impacts for each block, and the geographic distribution of the impacts.

A draft report by Rose (2002) describes a proposed approach to quantifying impacts using the function = $(\sum E_i \cdot \text{Area}_i) / (\sum \text{Area}_i)$ summed over all area in waters < 1,000 m deep (i.e, *fishable* EEZ waters). This is a single-valued metric which provides for simplified comparisons and evaluations. Ideally, any area summations would be weighted by habitat quantity and value as well, but such information is currently unknown and is set at 1.

In the analysis for this Programmatic SEIS, rather than summing the estimated impact block by block, the fishing intensity for each block is tabulated by intensity intervals as seen in Table 4.1-26. For example, in the Bering Sea 1,003 blocks were fished at an intensity level between 0.25 and 0.50, 822 blocks at an intensity level between 0.50 and 1.00 and so forth. This information can be used to estimate the mean relative impact level for all the fished blocks, or for all fishable blocks (<1,000m). This is approximated here by summing the frequency weighted midpoint impact levels and dividing by the number of fished blocks or number of fishable blocks. For example, for ρ=0.50 and q_H=0.10 the impact level for f=0.25 is 0.049 and for f=.50 is .095 with a midpoint of 0.072. The frequency weight of the interval 0.25 to 0.50 is 1,003. The interval midpoint impact levels are weighted and summed and divided for the Bering Sea by either 7,121 (no. of fished blocks) or 31,995 (no. of blocks <1,000 m in depth). For the more slow growing and more sensitive parameter scenario the mean impact of fished areas is 0.419 and 0.093 for all fishable blocks.

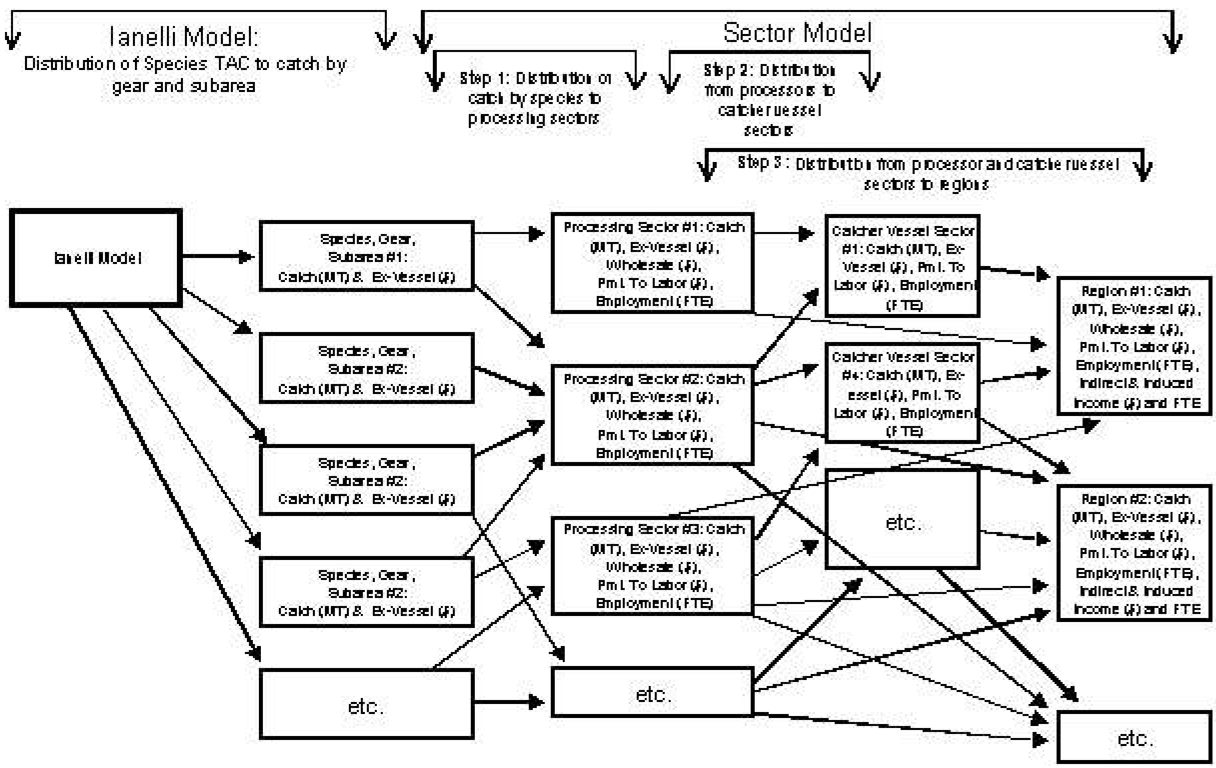
This approximation should produce mean impact levels similar to the more exact computation method demonstrated in a report by Rose (2002). Ideally, any area summations would be weighted by habitat quantity and value as well, but such information is currently unknown and neither computation takes into account differences in the unfished level of biostructure habitat or habitat suitability that probably exist. This is a single-valued metric which provides for simplified comparisons and evaluations. If all habitat over the fishable EEZ is of equal value to the productivity of the fisheries, then the simple mean impact estimates are indicative of the baseline fishing impacts. However, when summed over such broad categories of habitat, the mean impact value may not reflect effects, if impacts are concentrated on specific habitat types because not all habitat may be of equal value to stock productivity. Comparing impact expressed as a single value presumes the value of different levels of impacts is additive. That is, two units of habitat each impacted to H_{eq}=.75 (E=.25) are equivalent to two units of habitat, one heavily impacted to H_{eq}=0.50 (E=.50) and one unimpacted at H_{eq}=1.0 (E=0.0). Thus, the average impacts are equal in both cases, but the actual effect on the ecosystem may not be equivalent. One could argue that all else being equal, the latter case provides a wider range of habitat type and greater diversity over the same amount of habitat and is preferred over a uniform distribution of impact. In contrast, if H_{eq} only needs to be greater than 0.5 to be effective EFH, the former case would be preferred. Whatever the case may be, comparison of the frequency distribution provides increased discernment of potential impact. Thus, the distribution of the impacts needs to be considered.

In addition to computing mean impact levels, the model was also used in conjunction with the distribution information to further evaluate the baseline. While the mean impact values could be considered as indicating minor impacts, the distribution information shows that for the Bering Sea, for example, 552 + 277 = 829 blocks or over 8,000 sq. miles are fished at an intensity of f = 1.00 or greater (Table 4.1-26). For example, a map of the fishing distribution (Figure 4.1-10) shows that the heavily fished blocks are concentrated in a few large geographically extensive areas that are uninterrupted by any current fishing closures that may provide any protection or diversity in impact levels. The impact model estimates that those areas could have an impact level to bioshelter organisms of 18.1 percent or greater for the fast recovery rate parameter scenario or as much as 82.8 percent for the slow recovery rate/more sensitive scenario. Concern for areas where such potential impact could be occurring is a major consideration in the evaluation of the baseline and comparison of the alternatives.

General results using the habitat model are used qualitatively to evaluate the closure strategies of the alternatives. The rates of relative changes of catch and impact can be examined by combining the habitat impact model with standard fishery catch models. In general, closing large amounts of heavily fished area may not result in significant reduction in net habitat impact, as large amounts of effort are displaced. This results in increased impact levels in previously less heavily fished area. The potential for unforeseen consequences is high with such a large change in the system. A strategy of closing only lightly fished habitat reduces further impact in those areas while displacing only moderate amounts of effort to heavier fished areas. An increase of effort in already heavily fished habitat increases habitat impact relatively less than an increase in lightly fished habitat. Such a strategy, however, does not address potential ongoing impacts in heavily fished areas. A strategy of closing only small proportions of heavily fished habitat and increased proportions of lightly fished areas can achieve similar or greater reductions in impact with only moderate increases in effort in the remaining open areas. With closures located appropriately, this strategy can protect a cross section of habitat types and address the potential impacts of heavily fished habitat while minimizing economic effects and the chances of unforeseen consequences.

4.1.7 The Sector Model–an Adaptation of the Multi-Species Model Used for Estimating Socioeconomic Effects

The socioeconomic impacts of the alternatives have been estimated using an extension of the multi-species model based on the fishing and processing sectors and regions described in Section 3.9. For the remainder of this discussion the socioeconomic model extension is referred to as the "Sector Model." The sector model uses multi-species management model output of the species catch by gear and subarea, combined with the historical harvest and processing proportions, to estimate the distribution of catch and processing among the various sectors and regions that rely on the groundfish fishery. A schematic representation of the two models is shown below.



The Sector Model is a three-step process that:

1. estimates total catch and deliveries to processors;
2. proportions out deliveries to specific catcher vessel sectors;
3. distributes catches and processing amounts among the various regions where processors are located or vessels are owned.

In each step of the sector model, the catch of each species by gear and subarea gets distributed to successive sectors based on the historical distribution from 2001 (the baseline condition).

Perhaps the best way to describe the sector model is to take a specific output of the multi-species and run it through the sector model tracking the distribution at each step. For example, the multi-species pollock trawl sector catch from the Bering Sea in the year 2001 estimates that 1,472,600 mt of pollock from the Bering Sea will be harvested with trawl gear in 2003 under FMP 1. In step 1 of the sector model this pollock is distributed to each processor sector according to the proportion of the 2001 Bering Sea trawl pollock that sector processed (including discards). In addition to total catch, the model uses each sector's retention percentage, wholesale value per round ton, payments to labor per $ and employment (Full-Time Equivalent [FTE]/$) from 2001. These numbers are taken from the baseline conditions summarized in Section 3.9.2. Table 4.1-27 shows the 2001 conditions and how they are applied to generate the 2003 sector estimates for FMP 1. The results from Step 1of the Sector Model are used to estimate direct impacts of the alternative FMP bookends and the various processing sectors.

As shown in the upper portion of the table, surimi trawl CPs caught 35.3 percent of the 2001 pollock trawl harvest from the Bering Sea–retaining 99.8 percent of it. In the lower portion of the table, 35.3 percent of the 1,472,600 mt Bering Sea pollock trawl total under FMP 1 in 2003 is assigned to the surimi trawl CP sector. The table also shows that 99.8 percent of the 519.3 total was retained. At $604.4 per ton, the 2003 estimated product value for surimi trawl CPs is $313.8 million, with 35 percent of that ($109 million) estimated to be paid to labor represented by 1342.8 FTEs or 4.3 FTE per $million. A similar process is used for the other processing sectors.

Step 2 of the sector model distributes each processing sector's total retained catch amount back to the CVs that delivered it, based on the proportion of each processing sector's deliveries from CV sectors in 2001. The analysis developed, for each species, gear and subarea, a processor sector to CV sector distribution matrix based on 2001 deliveries, like the one for Bering Sea trawl pollock sector shown in Table 4.1-28. The table includes deliveries of CVs to surimi and fillet CPs as well as deliveries to shorebased processors, floaters and motherships. A very small percentage of the surimi and fillet trawl CPs totals were delivered by CVs, but 100 percent of the other sector's total were delivered. The row for the Bering Sea pollock shore plant sector indicates that 61.5 percent of their Bering Sea trawl pollock was delivered by Bering Sea trawl pollock CVs > 125 ft while Bering Sea trawl pollock CVs 60 to 124 ft delivered 34.8 percent. The remaining 3.6 percent was delivered by Diversified AFA trawl CVs and non-AFA trawl CVs. (Note that the CV sectors are defined and discussed in detail in Section 3.9.2.)

The percentages, like those in Table 4.1-28, are multiplied by the total for the species gear and subarea for each processor to generate the total retained catch assigned to each CV sector for the FMP and year. Ex-vessel prices, and payment to labor and employment factors are applied to retained catches to generate the remaining CV sector indicators. Table 4.1-29 illustrates this process with numbers for Bering Sea trawl pollock sector for FMP 1 in year 2003.

The third step of the Sector Model translates sector level activities to regional activities. This step is relatively complicated because the various sectors interact with regions in different ways as described below:

- **Shorebased Processors:** The Sector Model assumes that shorebased processors are very closely related to the regions in which they are located. In fact, the shore-based processors are designated according to their associated region. Two exceptions to this rule are the "Bering Sea Pollock Shore Plants" which are assigned to the Alaska Peninsula/Aleutian Islands Region, and the "Other States Shore Plants" are assigned to the Washington Inland Waters Region (because they are for the most part located in the Bellingham, WA). The Sector Model assumes that ex-vessel values attributed to shorebase processors are directly linked to the region through fish taxes. Further, the Sector Model assumes that all labor payments and employment of the shorebased processor accrue within the region. Finally, the Sector Model assumes that the expenditures of shorebased processors for deliveries of raw fish and other supplies, as well as the expenditures of their employees, will have indirect and induced impact within the region.[1]

- **Catcher Vessels:** CVs affect regions by making deliveries to processors and providing earnings for their returning owners and crew to spend in the region. When CVs make deliveries to processors located outside of the region they bring their earnings from outside into the region when they return. However, when CVs make deliveries to local processors, their earnings are already counted as expenditures by the local processor. Therefore, it is important to track not only the CV owner's home region but also the location to which they delivered. The sector model assumes that all earnings by region CV owners and crew contribute to the regional economy, but to avoid double counting, only the earnings from landing made outside the regions are used to calculate indirect and induce income and employment.[2]

- **At-Sea Processors (Catcher Processors, Motherships and Floating Processors):** The regional model assumes that at-sea processors generate most of their regional impacts in the region where their owners reside. The model assumes, primarily because better data are not available, that crewmembers on CPs and other at-sea processors are hired from the same region in which their owners reside.[3] Other economic impacts such as those resulting from purchases of equipment and supplies are also assumed to accrue to the vessel owner's region.

As indicated in the descriptions above, the sector model assigns regional impacts for shoreplants to the region in which they are located, and for vessels to the region in which their owner's reside. Therefore it is important to document the vessel owner's region. This documentation is accomplished using ownership information from NMFS and ADF&G. Table 4.1-30 is a matrix showing vessel owners' regional percentage for the pollock trawl fisheries for 2001. Similar matrices were developed for each species, gear, and area combination.

In Table 4.1-30, it is clear that the Washington Inland Waters Region is the dominant region for CPs and at-sea processors active in the 2001 pollock trawl fishery. The only other regions with at-sea processor owners

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[1]One of the Sector Model's shortcomings is that it is unable to track expenditures of processors and CVs in other regions. For example, many of the shorebased processing plants have headquarters offices in Seattle, and clearly some of their expenditure are made in the location of their headquarters. Further, because many of the employees of shorebased plants are seasonal, they are very likely to spend most of their earnings in their hometowns. The analysts believe first order expenditures Sector Model does a reasonable job estimating expenditure.

[2]Earnings of CVs owners and their crews resulting from deliveries to local processors are included in the estimated indirect and induced income and employment generated by shore base processors and therefore are not also calculated for the CVs. To do so would result in double counting and an overestimation of the effects of the fishing and processing industry.

[3]While this assumption is a simplification, and it is known that significant numbers of at-sea processing employees are not from the owner's region, the assumption is consistent with U.S. Department of Labor standards which assign at-sea employment to the region in which the vessel is based.

are Kodiak and other. A different picture is seen for the catcher vessels. While Washington is the dominant region for the Bering Sea pollock CVs (these vessels are all AFA qualified) the diversified AFA CVs, non-AFA trawl CVs and trawl CVs < 60 ft have much more diversified ownership patterns. For example, based on the ownership patterns of the sector, 27.4 percent of the Bering Sea pollock catch of diversified AFA CVs was assigned to the Kodiak region, while 9.8 percent was assigned to the Southcentral Alaska region.

Multiplying the numbers in the regional matrix in Table 4.1-30 by the catches by sector (Table 4.1-27 for CPs and at-sea processor and Table 4.1-29 for CVs) yields the regional apportionment of Bering Sea trawl pollock catches for 2003 from FMP 1 (as shown in Table 4.1-31). A similar process is used to assign catches of other species, gears, and areas to regions for other years and for the other FMP alternatives.

The next step in estimating regional effects of catcher vessels is distinguishing in-region deliveries and extra-regional deliveries. In-region deliveries are defined as deliveries to processing facilities assigned to the same region to which the catcher vessel is affiliated. For example, when a CV owned by a resident of Kodiak makes a delivery to a Kodiak shore plant, it would be considered an in-region delivery. When that same CV makes a delivery to an Alaska Peninsula/Aleutian Islands shore plant it would be considered an extra-regional delivery. It should be noted that at-sea deliveries are considered in-region if the both the owner of the CV and the owner of at-sea processors are from the same region. As indicated earlier the regional effect of CVs making an in-region delivery are counted as part of the regional shore-based processor effects, while the regional effects of extra-regional CV deliveries are assigned to the CVs. Table 4.1-32 shows the 2003 value of in-region and extra-regional deliveries of Bering Sea trawl pollock by the CVs sectors for FMP 1.

The Sector Model's final step calculates and assigns income and employment multipliers for each region. The multipliers relate total output in dollars from the fishing sector in a region to the additional indirect and induced income and employment that are generated. The multipliers are estimated with IMPLAN Version 2.[4] The IMPLAN software was used to create an economic (input-output) model of each the regions considered in this study. The regional input-output model is a mathematical representation of the inter-industry/institution transactions that occur within a defined economic region. The model traces how many times a dollar is re-spent within the regional economy before leaking out, and the economic impact of each round of spending. The economic base concept was used to determine the level of aggregation of the over 200 existing economic sectors that have backward linkages to the fishing sector in the regions considered. The multipliers for these economic base sectors (aggregated sectors) were generated from IMPLAN and used to determine the additional income and employment effects (secondary effects) that the fishing sector contribute to each of the regions. Table 4.1-33 shows the regional multipliers used in the analysis.

It is important to note that the Sector Model does not directly estimate inter-regional linkages. For example, the model does not specifically include income and employment resulting from expenditures of at-sea processors in regions outside of the vessel owners region. While it is clear that there are inter-regional effects, the data necessary to reasonably estimate those effects are not available. It is also important to note that the lack of inter-regional effects is offset to some extent by the assumption that all of the employment and income effect of shore-based processors occur within the processor's region.

[4] 1999 IMPLAN baseline data, the most current available, were used to estimate the multipliers.

Table 4.1-34 is an example of tables used in the regional effects assessment. The example shows the effects of the Bering Sea pollock trawl fishery on the Alaska Peninsula/Aleutian Islands Region for FMP 1 and 2003.